# 4.0 PLAN FORMULATION: POSSIBLE SOLUTIONS

This chapter describes the development of alternative plans that address the planning objectives, the comparison of those plans and the tentative selection of a plan. It also describes the tentatively selected plan and its implementation requirements.

## 4.1 Plan Formulation Rationale

A wide variety of management measures were developed to address one or more of the planning objectives. These measures were evaluated and screened. Alternative plans were then developed, comprised of one or more of the management measures.

## 4.2 Formulation of Alternatives

### 4.2.1 Watershed

Because the watershed was the source of past unnatural sedimentation in the lagoon, a watershed study was conducted concurrently with the Feasibility Study to identify potential restoration sites (that is, sediment control sites) in the watershed. However, based on the results of the *Bolinas Lagoon Watershed Study*, completed in November 2001, no watershed-based restoration alternatives were developed for this study. Any future work in the watershed will be coordinated by a Bolinas Lagoon Watershed Council, individual property owners, or others. Following are the conclusions listed in Section 6 (Conclusions) of the watershed study (found in Appendix A of the EIS/EIR):

- Bolinas Lagoon was never a deep embayment, although it may be shallower now than it was 150 years ago.

- Current erosion rates appear to be close to background rates.

- The most likely reason for the dramatic increase in sediment deposition rates is "wide scale timber harvest for lumber that was followed by harvesting for firewood, which was furthermore concurrent with mining and ranching operations in the watershed. After these activities stopped, and the watershed was in early stages of recovery, a fire (or series of fires) burned through a large portion of the watershed causing wide-scale erosion."

- It is unlikely that any changes to management practices within the watershed would have a significant effect on sedimentation rates within the lagoon.

- Most of the sediment entering the lagoon via the watershed is derived from natural mass wasting erosion, and is an order of magnitude less than the potential volume mobilized by the tide.

• One area that could be restored to help further reduce the amount of sediment entering the lagoon would be at Pine Gulch Creek. Restoration of the lower reach, where it is currently diked, could reduce the amount of fine sediment transported into the lagoon by allowing it to deposit on the floodplain instead.

### 4.2.2 Bolinas Lagoon

Since the immediate concern for the lagoon was the diminishing value of habitat due to sedimentation, all of the restoration alternatives in this study consist of removing sediment and fill areas from the lagoon. The restoration components were specifically designed to remove sediment from areas of the lagoon where accretion was the highest in order to recreate some of the historical habitat values. Each component was designed in a historical context to ensure that any changes in the lagoon system would mimic past conditions. Historical data used for the development of the alternatives include:

1. Aerial photographs from 1942 to 1998
2. Bathymetric data and maps from 1968, 1978, 1988, and 1998
3. Lagoon maps, or black and white drawings, dating back to the 1800's
4. Historical reports, most of which were included in the 1996 Bolinas Lagoon Management Plan (BLMP 1996)
5. Numerical modeling input

From this information, the areas with the greatest accretion, and the features most affected by the lagoon's above-normal sedimentation rate were evident.

## 4.3 Restoration Measures

A management measure (or restoration measure, as they are referred to in this study) is a feature, or activity, at a particular site that addresses one or more of the planning objectives. A wide variety of measures were considered throughout the Feasibility Study. As the study progressed, ideas on how to remedy the problem in the lagoon were proposed by the local communities, local sponsor, and the BLTAC, which were already involved in the project development, and refinements were generated by the HEEP after its review of the alternatives. Some were found to be infeasible due to technical, economic, or environmental constraints, and others were carried forward for further analysis. Each measure was assessed, and a determination was made regarding whether it should be retained in the formulation of alternative plans. An evaluation of the restoration measures, after they were combined to form alternatives and alternative plans, is presented in subsequent chapters.

There are nine areas being considered for sediment removal. The Pine Gulch Creek Delta component has two variations that are addressed separately, making a total of ten individual components, covering all areas of the lagoon. A summary of the footprint surface areas (acres) and dredge volumes (cubic yards) can be seen in Figure 4.1, page 4-4. A map of the component locations can be seen in Figure 4.2, page 4-5, and it should be referenced for the location of each component as it is discussed. The ten components will be discussed in an order roughly from north to south.

### 4.3.1 No Action

The Corps is required to consider the option of "No Action" as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). With the No Action plan, which is synonymous with "Without Project Condition," it is assumed that no project would be implemented by the Federal Government or by local interests to achieve the planning objectives. The No Action Plan forms the basis against which all other alternative plans are measured. Since this plan is required by NEPA to be included among the candidate plans in the final array of alternatives, it is described in more detail in Section 4.6.1 of this chapter.

### 4.3.2 North Basin

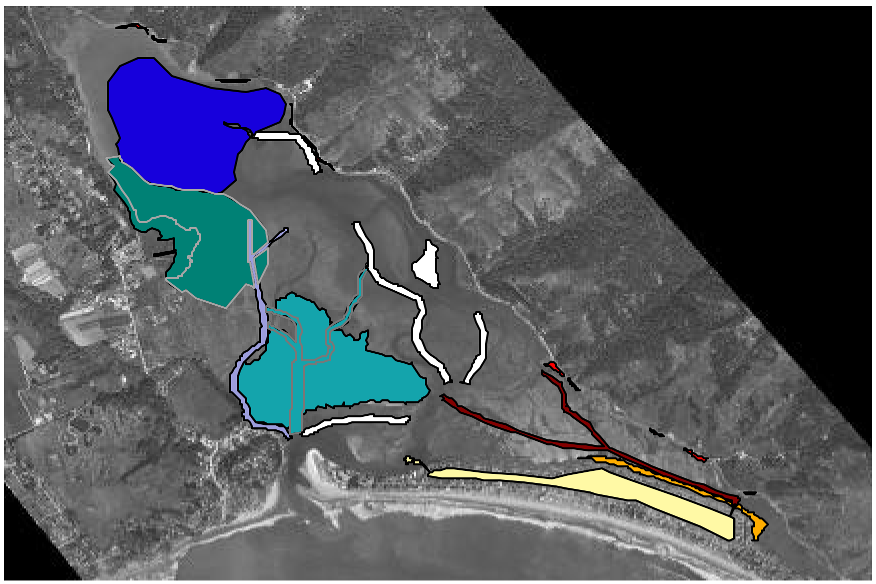
The North Basin component was designed to restore the basin area historically present in the northern end of the lagoon. Because of its large surface area and volume, the tidal prism, and the distance that tidal prism travels, is greatly increased with this restoration component. Coupling the North Basin and Main Channel components increases the effectiveness of the basin by connecting it to the inlet and allowing for a greater volume of water to reach the northern end of the lagoon. In turn, dredging the North Basin would help maintain the Main Channel. The configuration of the North Basin component is shown in the color blue in Figure 4.2 (page 4-5).

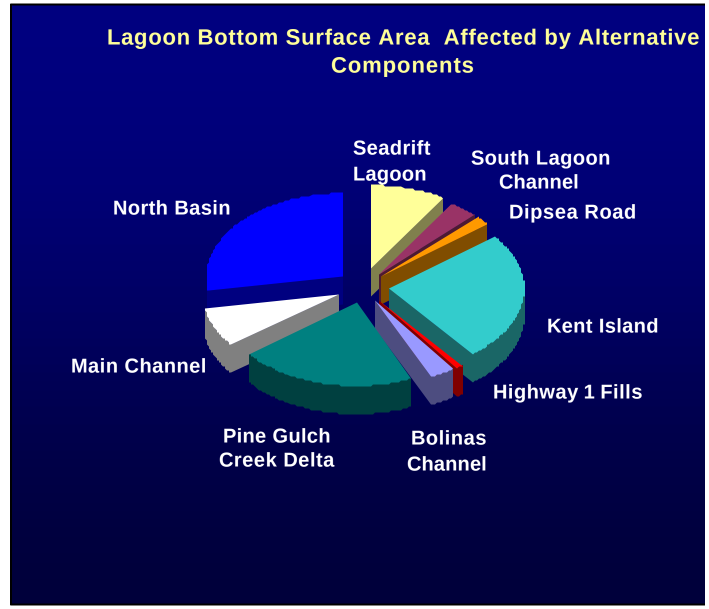
As seen in Figures 3.7 and 3.8 (from Chapter 3), the north end of the lagoon has experienced some of the most severe accretion. Since the north end was once relatively deep, and the velocity of water currents in this area have been relatively low, it has acted as a sediment basin, accumulating much of the sediment entering from the eastern shore streams and Pine Gulch Creek.

Dredging the North Basin would decrease upland habitat surface area by 0.18 acres (Table 4.1, page 4-19). As discussed in Section 3.3.2, upland habitat volume will not be used as a habitat measure in this Feasibility Study as it does not provide useful information on upland habitat changes. Intertidal habitat volume would increase by 167,000 cubic yards (cy), but would decrease the intertidal habitat acres by 107 acres (Table 4.2, page 4-19). This discrepancy can be attributed to the natural dynamics of the lagoon: as tidal prism increases, the volume of intertidal habitat increases because of a larger tidal range (i.e., lower low tides and higher high tides). Because the lagoon is a habitat with three dimensions, habitat acres, which measure surface area, might decrease, even though the total volume of habitat increases. Essentially, an increase in intertidal volume signifies an overall increase in intertidal habitat. Subtidal habitat would increase by 292,000 cy in volume and 107 acres (Table 4.3, page 4-19).

## Component Footprint Areas and Dredge Volumes

| Component | Surface Area acres | Volume $yds^3$ |
|---|---|---|
| Bolinas Channel | 15.57 | 130,799 |
| Pine Gulch Creek Delta (Estuarine) | 102.82 | 190,706 |
| Pine Gulch Creek Delta (Riparian) | 86.32 | 158,617 |
| Dipsea Road | 7.97 | 37,692 |
| Highway 1 Fills | 3.25 | 4,828 |
| Kent Island | 124.06 | 376,748 |
| Seadrift Lagoon | 43.47 | 44,958 |
| South Lagoon Channel | 17.58 | 89,246 |
| Main Channel | 37.49 | 216,241 |
| North Basin | 136.11 | 458,538 |





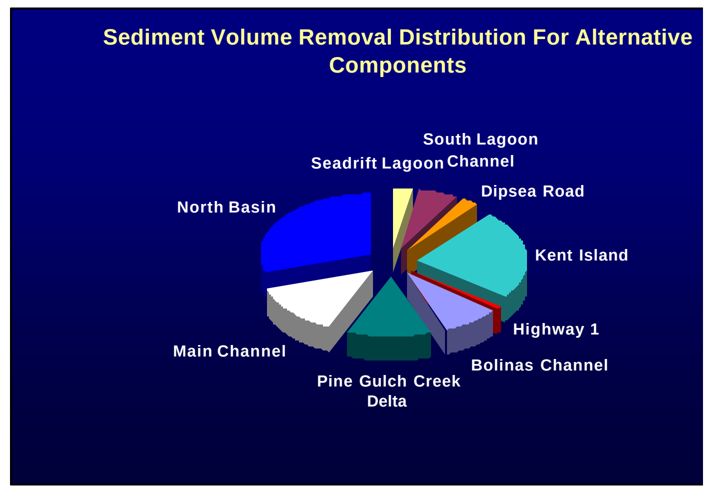




*Figure 4.1 Volume, Surface Area and Location of Restoration Components*

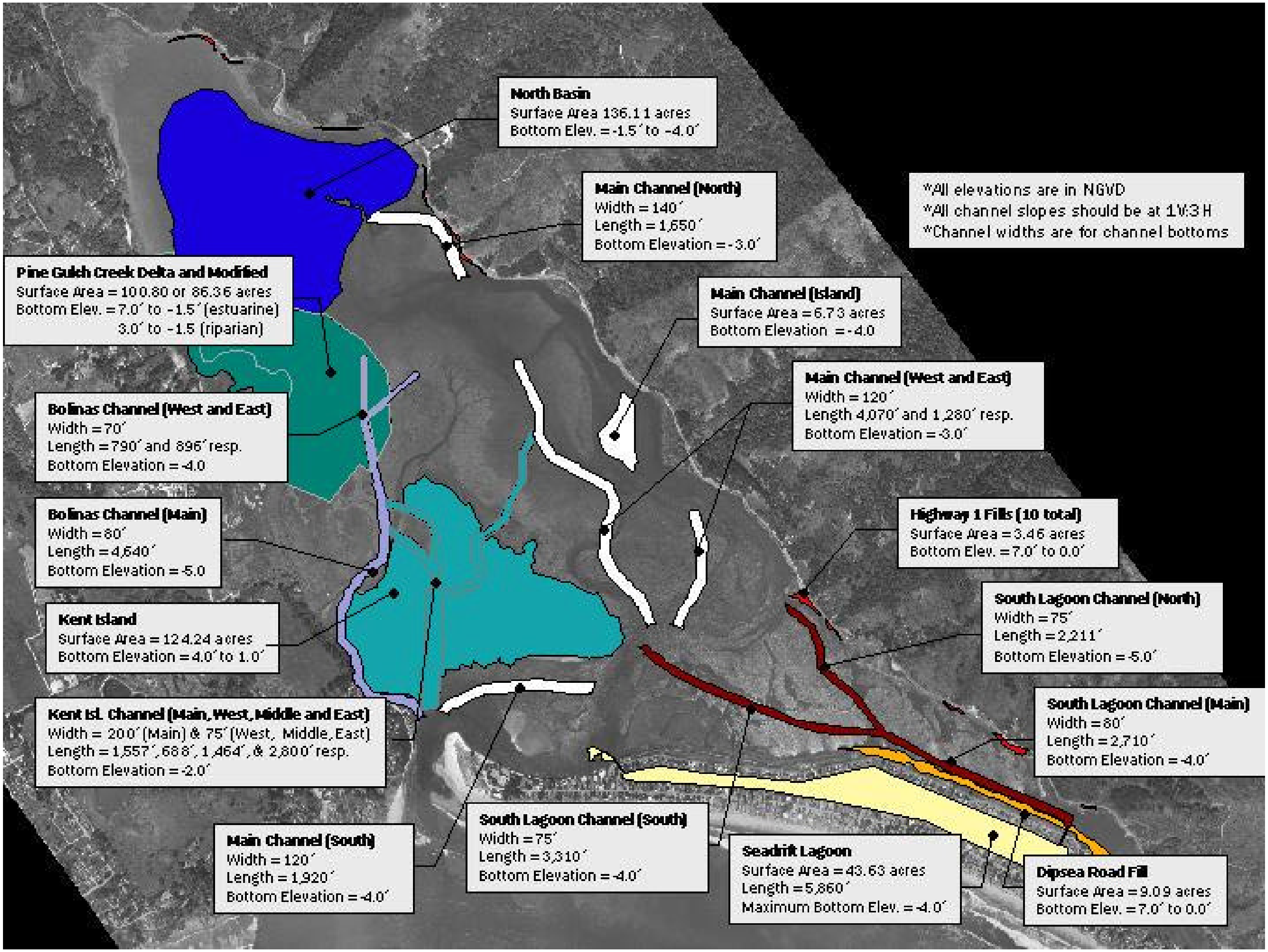



*Figure 4.2 Dimensions of Restoration Components*

Overall, this component significantly increases subtidal habitat volume, and increases intertidal habitat volume to a great degree. Benefits derived from an increase in these habitats include improved habitat quality for migratory bird species, harbor seals, invertebrates, benthos, plankton, and a variety of fish species inhabiting the lagoon, as well as increased accessibility to Pine Gulch Creek for anadramous fish species, including steelhead and salmon.

The basin would be dredged between the –1 foot and –4 feet NGVD contours. As shown in Figure 4.1 (page 4-4), the North Basin would have a construction footprint of 136 acres, and 459,000 cy of material would be removed. The material would be removed by hydraulic cutterhead dredge, pumped through a pipeline to a barge moored in Bolinas Bay.

### 4.3.3 Main Channel

As seen in Figures 3.7 and 3.8 (from Chapter 3), the size of the Main Channel has been decreased both in depth and in width by accumulated sediments. In order to provide sufficient flow to the north end of the lagoon, the Main Channel (the channel that runs between Kent Island and the Stinson Beach sand spit, and also runs parallel to Highway One on the east side of lagoon) would be dredged at the locations indicated by the color white in Figure 4.2 (page 4-5). Four sections of the channel would be deepened or reestablished, and one "island" in the Main Channel would be removed.

Dredging the Main Channel would not decrease or increase upland habitat surface area (Table 1, page 4-19). What is considered upland habitat for this component (that is, habitat above the tidal range) could be considered intertidal habitat for all intents and purposes, considering the location and function of the main channel. The increase in intertidal and subtidal habitat volume would be similar but, overall, there would be a greater increase in subtidal habitat surface area. Intertidal habitat would increase by 109,000 cy in volume, and decrease by 32 acres (due to the dynamics explained earlier) (Table 4.2, page 4-19). Subtidal habitat would increase by 108,000 cy in volume, and 32 acres (Table 4.3, page 4-19).

All channel sections, with the exception of the most southerly channel section, would be lowered to –3 feet NGVD, with side slopes of one foot of vertical height for every three feet of horizontal width (1V:3H). The most southerly section would be lowered to –4 feet NGVD, with side slopes of 1V:3H. The island area would be lowered to an elevation of –4 feet NGVD. The Main Channel component would have a construction footprint of 37 acres, and would remove 216,000 cy of material (Figure 4.1, page 4-4). Material would be removed by hydraulic cutterhead dredge and pumped through a pipeline to a barge moored in Bolinas Bay.

### 4.3.4 Highway One Fills

The sediment removal locations for the Highway One Fills component are indicated by the color red in Figure 4.2 (page 4-5). Fill would be removed from ten sites along the eastern border of the lagoon at Highway One; these sites can be characterized as unnecessary turnouts, unauthorized disposal sites and, in general, areas that were filled in at some point in the past. The public identified this component as an area to remove excessive fill material and restore intertidal habitat. Upland habitat surface area would increase by 0.40 acres (Table 4.1, page 4-19). Intertidal habitat surface area would increase by 0.53 acres, and intertidal habitat volume would increase by 2,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area and volume would not increase (Table 4.3, page 4-19). The overall habitat gain with this component would be intertidal habitat. Although the overall increase in desirable habitats is not large, this component does remove some known human impacts from the system.

At each of the ten sites, material would be removed between a minimum elevation of 0 feet NGVD and a maximum elevation of 5 feet NGVD. The Highway One Fills component would have a construction footprint of 3 acres, and would remove 4,800 cy (Figure 4.1, page 4-4). The material at the Highway One sites would be removed with land-based equipment.

### 4.3.5 Pine Gulch Creek Delta (Estuarine)

The Pine Gulch Creek Delta restoration component is indicated by the color green in Figure 4.2 (page 4-5). The full green area comprises the Estuarine component, whereas the Riparian component skirts around the riparian habitat area, which is higher in elevation on the delta and designated by a line in the figure. Nothing west of the demarcation line would be removed with the Riparian component. The Pine Gulch Creek Delta component was designed to remove portions of the large deltaic formation on the west side of the lagoon that has formed over time due to unnaturally high sedimentation from Pine Gulch Creek. As shown in the historical aerial photos, Figures 4.3 through 4.7 (pages 4-8 through 4-12) it has grown significantly in surface area and elevation. In order to increase intertidal and subtidal habitat in this area, some of the existing salt marsh, upland and riparian habitat would be removed. The overall change in habitat composition in this area would be from upland and high intertidal habitat to low intertidal and subtidal habitat. Upland habitat surface area would decrease by 11 acres (Table 4.1, page 4-19).

Intertidal habitat surface area would increase by 8 acres, and intertidal habitat volume would increase by 155,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 4 acres and subtidal habitat volume would increase by 813 cy (Table 4.3, page 4-19). Overall, the most significant habitat gains for this component are in intertidal habitat surface area and volume.

Approximately 1 foot to 1.5 feet of material would be removed from the existing grade between the – 1.5 feet NGVD and 7 feet NGVD contours. This would require the removal of 7 out of 17 acres of riparian habitat. The land above the expected water level (3 feet to 4 feet NGVD) would have to be graded in order to maintain a slope that more closely approximates the existing slope. The Pine Gulch Creek Delta (Estuarine) component would have a construction footprint of 103 acres and would remove 191,000

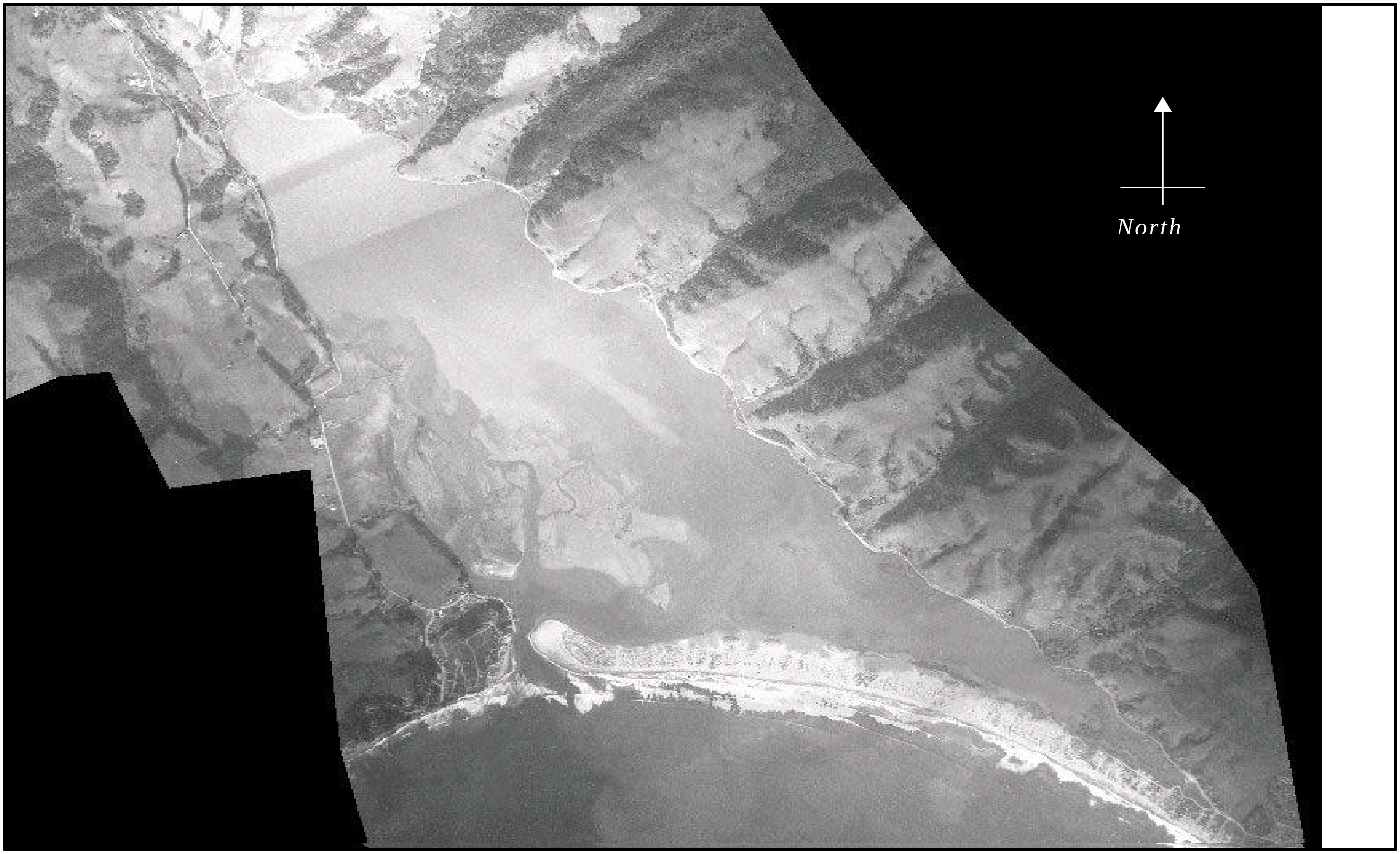



*Figure 4.3 Historical Aerial Photo From 1942*

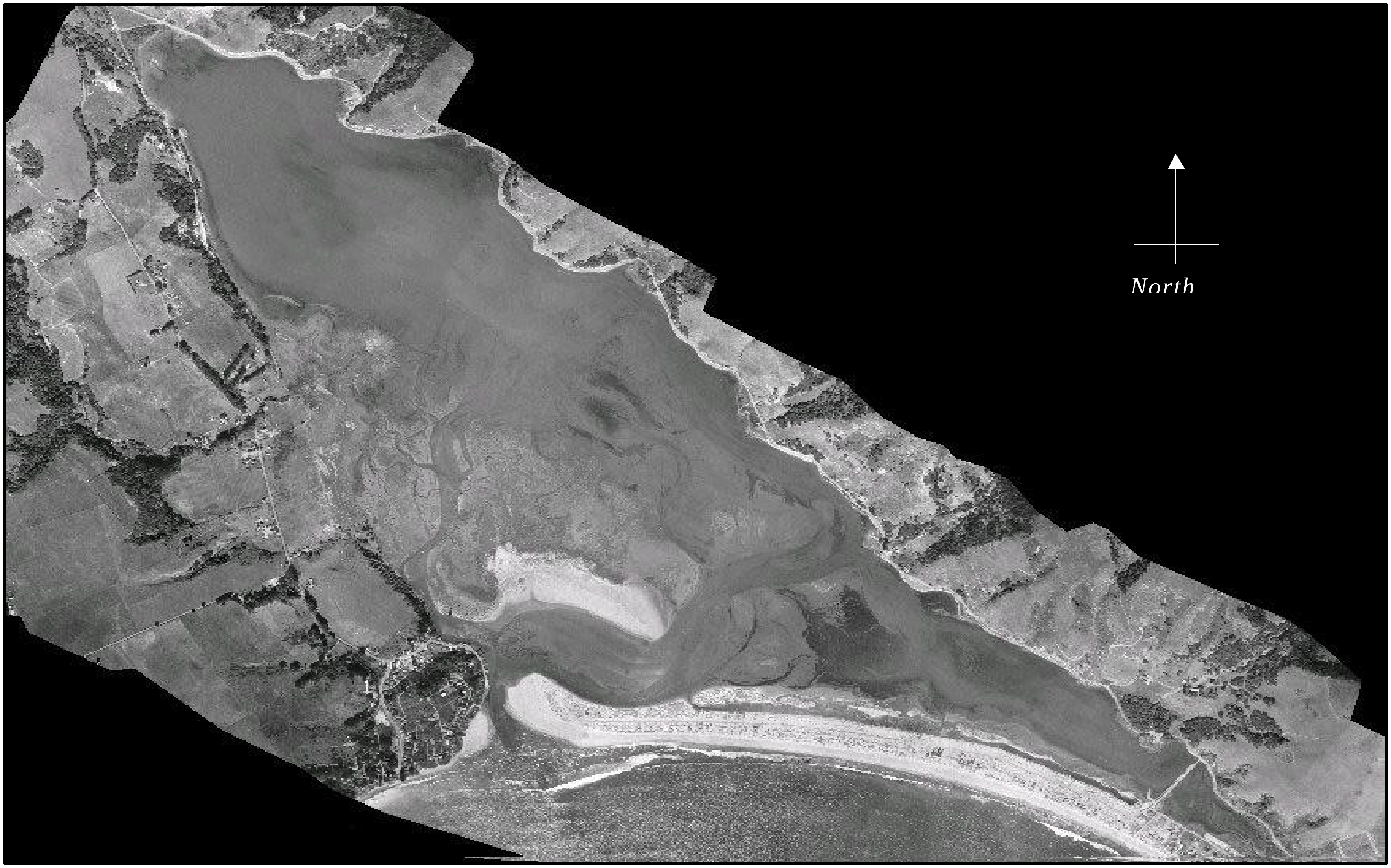



*Figure 4.4 Historical Aerial Photo From 1959*

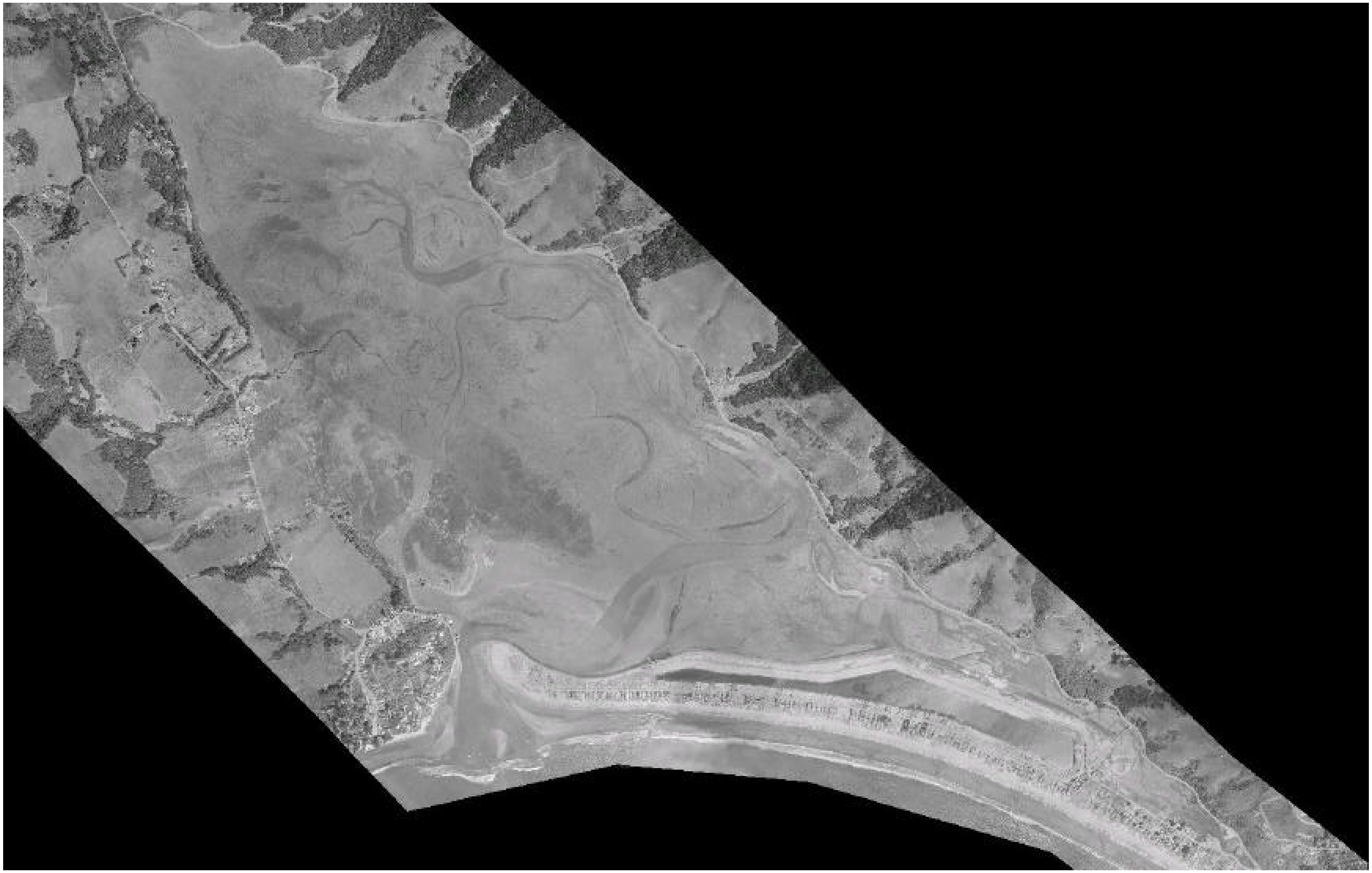


*Figure 4.5 Historical Aerial Photo From 1968*

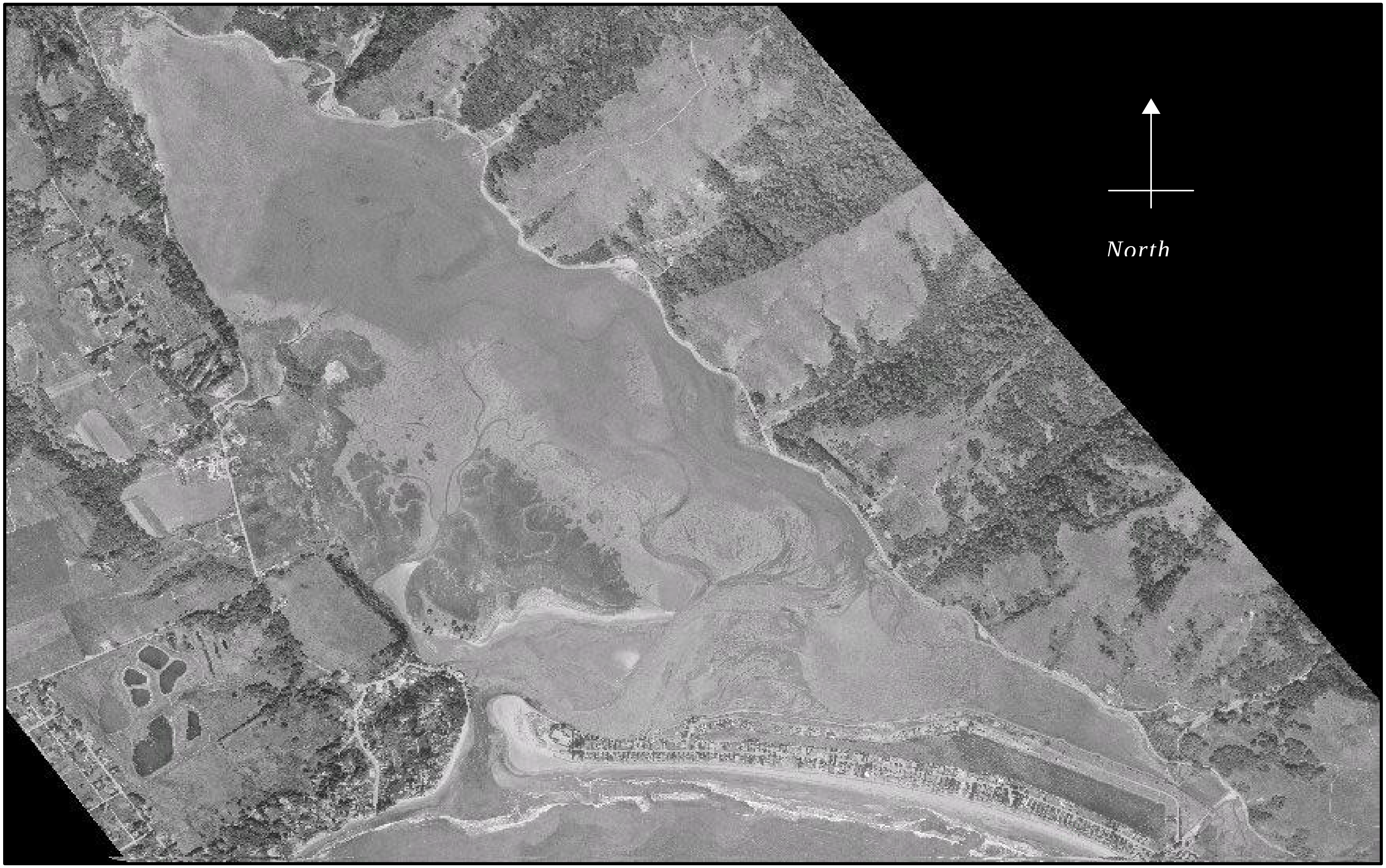



*Figure 4.6 Historical Aerial Photo From 1984*

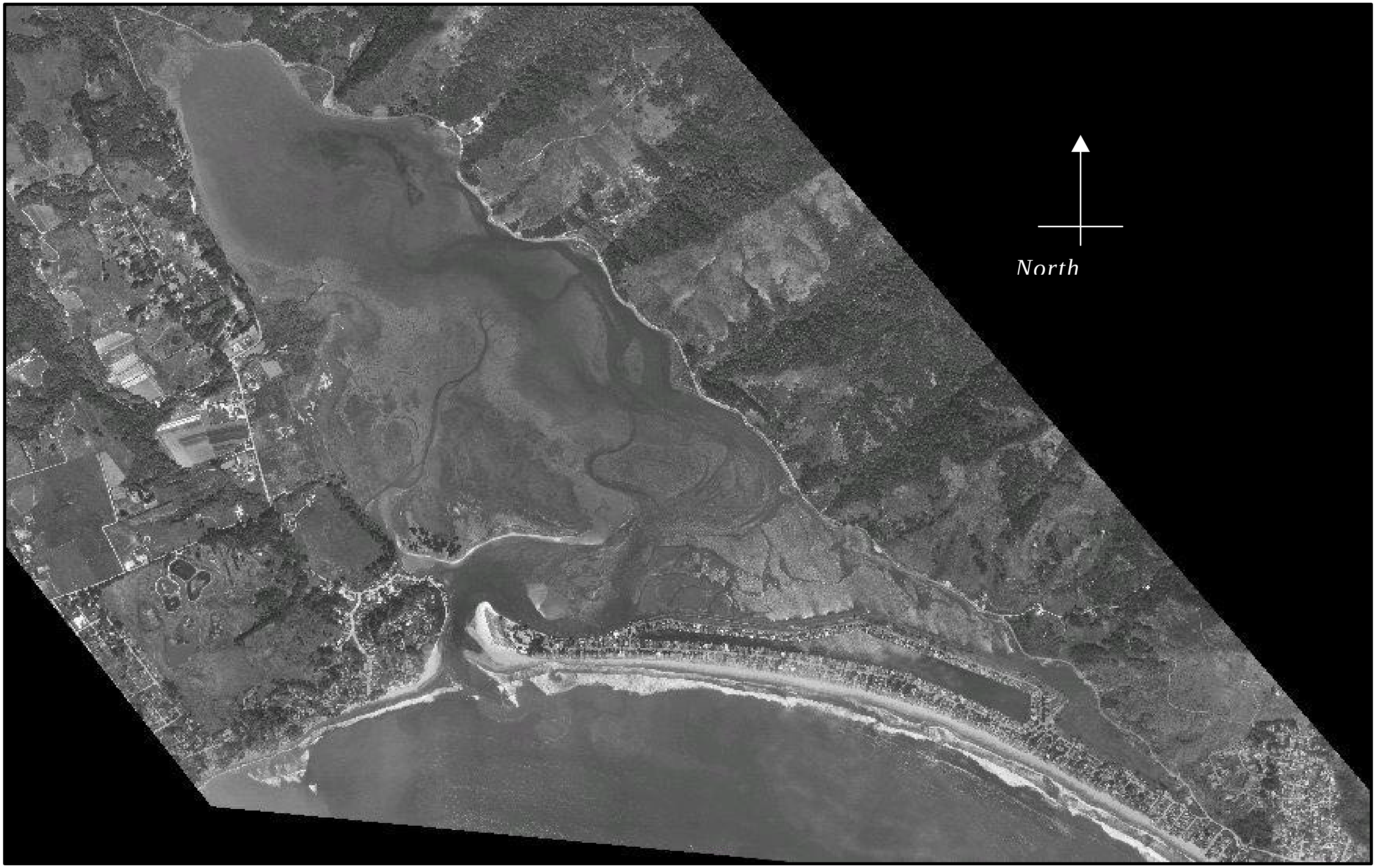



*Figure 4.7 Historical Aerial Photo From 1997*

cy (Figure 4.1, page 4-4). A portion of the material, in areas too deep to reach with land-based equipment, would be removed with a hydraulic cutterhead dredge. This wet material would be pumped through a floating pipeline across the tip of the Stinson Beach sand spit to a barge moored in Bolinas Bay.

### 4.3.6 Pine Gulch Creek Delta (Riparian)

Like the Pine Gulch Creek Delta (Estuarine) component, this alternative would remove portions of the large deltaic formation on the west side of the lagoon. However, it would avoid the riparian habitat area entirely. The overall change in habitat composition in this area would be from upland and high intertidal habitat to low intertidal and subtidal habitat. Upland habitat surface area would decrease by 9 acres (Table 4.1, page 4-19). Intertidal habitat surface area would increase by 5 acres, and intertidal habitat volume would increase by 148,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 4 acres, and subtidal habitat volume would increase by 810 cy (Table 4.3, page 4-19). Overall, the most significant habitat gains for this component are intertidal habitat surface area and volume. Although this component avoids the riparian area of Pine Gulch Creek and removes less material overall, this component should be thought of as being nearly identical to the Estuarine component, the only difference being that the Riparian component removes none of the 17 acres of riparian habitat. The difference in volume would be within the range of error for the data, and therefore, the volumes for the two components should be thought of as being nearly equal.

Again, approximately 1 foot to 1.5 feet of material would be removed from the existing grade between the – 1.5 feet NGVD and 4 feet NGVD contours. Since none of the riparian habitat would be removed, however, the slope between upland habitat and subtidal habitat would be steeper. The Pine Gulch Creek (Riparian) component would have a construction footprint of 86 acres and would remove 159,000 cy of material (Figure 4.1, page 4-4). The majority of the material would be removed via land-based equipment. A portion of the material, in areas too deep to reach with land-based equipment, would be removed with a hydraulic cutterhead dredge. This wet material would be pumped through a floating pipeline across the tip of the Stinson Beach sand spit to a barge moored in Bolinas Bay.

### 4.3.7 Bolinas Channel

This component would deepen the channel that originates near the inlet of the lagoon, flows between Kent Island and the town of Bolinas, continues northerly, and terminates at the Pine Gulch Creek Delta (the channel runs along the east bank of the delta). The color lavender in Figure 4.2 (page 4-5) indicates Bolinas Channel. The overall habitat change created by this restoration component would be a significant increase in intertidal and subtidal habitats. Upland habitat surface area would decrease by 3 acres (Table 4.1, page 4-19). Intertidal habitat surface area would decrease by 11 acres, but intertidal habitat volume would increase by 63,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 14 acres, and subtidal habitat volume would increase by 66,000 cy (Table 4.3, page 4-19). Other benefits include improved habitat for subtidal species, including potential new habitat area for eelgrass that was historically present in the channel, and increased access and use of the area by fish that inhabit Pine Gulch Creek. Along with an improvement in the subtidal and intertidal habitats would be a larger food base for predatory species like certain birds, sharks, and seals.

As shown in Figures 4.3 through 4.7 (pages 4-8 through 4-12) the channel has experienced noticeable morphological changes over time, and has become very shallow and narrow. Bolinas channel would be dredged to a depth of –5.0 feet NGVD with side slopes of 1V:3H, with the exception of the two forks, which would be dredged to a depth of –4.0 feet NGVD with side slopes of 1V:3H. The Bolinas Channel component would have a construction footprint of 16 acres and would remove 131,000 cy of material (Figure 4.1, page 4-4). The material would be removed with a shallow draft hydraulic cutterhead dredge. The material would be pumped through a floating pipeline, which would most likely exit the lagoon across the very tip of the Stinson Beach sand spit to a barge moored in Bolinas Bay.

### 4.3.8 Kent Island

The Kent Island restoration component is indicated by the color aqua in Figure 4.2 (page 4-5). This alternative would restore the historical channel system through Kent Island that is evident in the 1942 photo (Figure 4.3, page 4-8). Restoring this system of channels would, in effect, create a series of flood shoal islands through which water would flow farther up in the lagoon. Water flowing in through the inlet would be directed towards the northern part of the lagoon, increasing tidal prism and the distance that tidal prism travels, an important part of keeping the inlet open. In essence, construction of the Kent Island component would recapture lost habitat and lost habitat values, and the islands would become shoaling islands where future sedimentation would accumulate. This, in turn, should foster the growth of new wetland habitat over the long term, providing additional habitat benefits. Although some emergent salt marsh habitat would be removed during construction, the benefit of this component is the increase in intertidal and subtidal habitat, which do not have sediment-trapping qualities like emergent salt marsh. After years of sediment accretion, salt marsh habitat would likely form again on the island.

Overall, the Kent Island restoration component would bring about a significant increase in lower intertidal habitat and a moderate increase in subtidal habitat. Upland habitat surface area would decrease by 64 acres (Table 4.1, page 4-19). Intertidal habitat surface area would increase by 48 acres, and intertidal habitat volume would increase by 231,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 16 acres, and subtidal habitat volume would increase by 16,000 cy (Table 4.3, page 4-19).

The main part of the channel flowing through the center of the island would be 200 feet wide, have side slopes of 1V:3H, and have a bottom elevation of –2.0 feet NGVD. At the northern portion of Kent Island, the channel would split into three sub channels, each with a width of 75 feet, side slopes of 1V:3H, and bottom elevations of –2.0 feet NGVD. The island would also be reduced in overall size by lowering its existing elevation by 1 to 2 feet. The Kent Island component would have a construction footprint of 124 acres and would remove 377,000 cy of material (Figure 4.1, page 4-4). As shown in Figures 4.3 through 4.7 (pages 4-8 through 4-12) Kent Island has grown significantly in size and elevation, and now consists of a large upland area where non-native plant species such as Monterey Pines have become established.

The material at Kent Island would be removed with a shallow cutterhead hydraulic dredge, and would be pumped through a floating pipeline across the tip of the Stinson Beach sand spit to a barge moored in Bolinas Bay. Material that is too dry to be removed by hydraulic dredge, like trees and other vegetation, would be removed with land-based equipment. This equipment would have to be brought in by barge. The mulched material would be transported to Bodega Bay by barge, where it would either be loaded on to trucks and taken to an upland disposal site, or distributed for sale.

### 4.3.9 South Lagoon Channel

The South Lagoon Channel would be constructed in the southeast portion of the lagoon, acting as a link between the Main Channel in Bolinas Lagoon and the eastern channel that would exit Seadrift Lagoon (if the Seadrift Lagoon component were constructed). This component is indicated by the color burgundy in Figure 4.2 (page 4-5). Overall, construction of the South Lagoon Channel would increase subtidal habitat to a great extent, and would increase intertidal habitat somewhat. Upland habitat surface area would decrease by 0.07 acres (Table 4.1, page 4-19). Intertidal habitat surface area would increase by 14 acres, and intertidal habitat volume would increase by 25,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 13.93 acres, and subtidal habitat volume would increase by 63,000 cy (Table 4.3, page 4-19). A major benefit of this component is an increase in the tidal flow and flushing capacity of both lagoons. Other benefits include improved habitat for subtidal species, and increased access and use of the area by fish that inhabit Easkoot Creek.

The channel would consist of a main portion that runs parallel to Dipsea Road, and two branches that extend to the Main Channel. The extensions and main section would have a bottom elevation of –4 feet NGVD and side slopes of 1V:3H. The channel would be dredged using a shallow draft cutterhead hydraulic dredge, with the material being pumped to a barge in Bolinas Bay. The South Lagoon Channel component would have a construction footprint of 18 acres and would remove 89,000 cy of material (Figure 4.1, page 4-4).

### 4.3.10 Dipsea Road Fill

The Dipsea Road Fill restoration component would remove fill material between the elevation of 0 feet and 7 feet NGVD along Dipsea Road, as indicated by the color orange in Figure 4.2 (page 4-5). Due to regulations governing Bolinas Lagoon, septic fields (leach fields) cannot be closer than 100 feet to the edge of the water. Therefore, to maintain water quality standards in Bolinas Lagoon, fill would only be removed from areas in excess of 100 feet from the road (conservatively, the outer edge of the septic fields). Overall, this restoration component increases the amount of intertidal habitat, which is created directly from converting upland fill habitat to intertidal habitat. Upland habitat surface area would decrease by 2 acres (Table 4.1, page 4-19). Intertidal habitat surface area would increase by 3 acres, and intertidal habitat volume would increase by 14,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 0.10 acres, and subtidal habitat volume would increase by 333 cy (Table 4.3, page 4-19). The Dipsea Road Fill component would have a construction footprint of 8 acres, and would remove 38,000 cy of material (Figure 4.1, page 4-4). Because most of the material being removed is upland material, most of it would be removed with land-based equipment.

### 4.3.11 Seadrift Lagoon

Construction of the Seadrift Lagoon component would remove the thin, silty organic layer of sediment known to contain copper sulfate, and would open the lagoon at both ends to tidal flushing. The color yellow in Figure 4.2 (page 4-5) indicates the Seadrift Lagoon component. The general idea behind the design of the Seadrift Lagoon component was to open up the inner lagoon to tidal flushing, recapturing some of the tidal prism that was lost when the Seadrift housing development was constructed. As it currently exists, there is little tidal influence in the lagoon; water is brought in on the highest tides to “replenish” the water in Seadrift Lagoon, but it is not open to full tidal flushing.

Overall, the Seadrift Lagoon component would create a significant increase in intertidal habitat, and would increase subtidal habitat to a great extent. Upland habitat surface area would decrease by 42 acres, most notably in the channels that are to be constructed where currently there is land (Table 4.1, page 4-19). Intertidal habitat surface area would increase by 7 acres, and intertidal habitat volume would increase by 245,000 cy (Table 4.2, page 4-19). Subtidal habitat surface area would increase by 35 acres, and subtidal habitat volume would increase by 186,000 cy (Table 4.3, page 4-19). The Seadrift Lagoon component would have a construction footprint of 43 acres, and would remove 45,000 cy of material (Figure 4.1, page 4-4). Along with the habitat changes, other benefits include an increase in tidal prism and flushing capacity in Bolinas Lagoon. The habitat currently available to wildlife is minimal (and of lower quality) because of its brackish nature, minimal flushing, and homogeneity of habitat types. By opening the lagoon, not only would the tidal prism in Bolinas Lagoon increase, but the value of existing habitat would also improve. One ecological concern that has been raised with this component is the presence of green crabs (an invasive species) in Seadrift Lagoon. If Seadrift were opened to tidal flushing, would it act as a “source” for green crabs in Bolinas Lagoon? This question has yet to be answered.

<u>Variation 1</u>: This alternative would open the now “closed” Seadrift Lagoon to full tidal flushing by replacing the existing culverts in their present locations with a total of six (6) 4 foot by 6 foot concrete box culverts. Three (3) would be placed at either end of the lagoon. Currently there is a 15-foot culvert easement at the southeast end of Seadrift

Lagoon where half of the culverts would be placed. It is assumed this area would be sufficient for construction of this option, but it is unknown at this point what footprint would be permissible there. Also, at the northwest end, the existing culverts run underneath a mature cypress tree, as well as a portion of a private garage. Installation would require the removal of the tree and the structure. The local sponsor would pay damages to the owner of the structure as a part of the Lands, Easements, Rights-of-Way and Relocations fs(LERR) costs which are always the responsibility of the local sponsor, and part of their 35% cost share. One option at this end of the lagoon would be to install the culverts at the boat ramp area directly adjacent to the existing culverts, and fill the old culverts with concrete.

Variation 2: An alternative to the culverts for opening Seadrift Lagoon to full tidal flushing would be replacing the six (6) culverts with two (2) twenty (20) foot-wide open channels, one at either end. The channel at the southeast end would follow the same path as the existing culverts, whereas at the northwest end, the channel could be installed in the location of the existing boat ramp, which would be reconstructed at another location along Dipsea Road. A bridge would have to be constructed on Dipsea Road over both channels. Installing culverts at one end, with open channels at the other end, is another possibility.

Variation 3: A third variation of this component would be to use one entrance channel or one set of three (3) culverts at the northwest end only. This option would open Seadrift Lagoon to limited tidal action, and only at the northern end. With this variation, tidal water would come in and out of Seadrift Lagoon, but it would *not* flow through Seadrift Lagoon into the southern end of Bolinas Lagoon. Detailed numerical modeling of Seadrift Lagoon would have to be performed to determine the hydrological effects of this variation.

Out of the three variations, the Corps study team recommends Variation 2 due to the relative ease of operation and maintenance and potential additional environmental benefits resulting from having an open system. In Variation 1, the culverts would be over three hundred (300) feet long, creating long term maintenance issues for the local sponsor, even if larger box culverts were installed. In Variation 3, fewer environmental benefits would be realized because the tidal range in Seadrift Lagoon would be lower. Therefore, in all subsequent discussions referring to the Seadrift Lagoon component, Variation 2 is the assumed configuration. It is important to note that with Variation 2, up to 1,000 feet of sheet pile wall would be installed near the lagoon inlets to prevent erosion. The rest of the lagoon would not need new sheet pile since water current speeds would be low, and dredging would be minimal near the existing walls. Preliminary geotechnical analyses show that the stability of those walls should not be affected.

## 4.4 Formulation of Alternatives

As part of the plan formulation process of the Bolinas Lagoon Ecosystem Restoration study, a Habitat Evaluation Expert Panel was assembled and convened by Marin County and the Corps, in cooperation with the Bolinas Lagoon Technical Advisory

Committee. The primary purpose of the expert panel was to evaluate the environmental merits of the proposed restoration components. Although the panel found that they could not rank the components based on environmental criteria, as originally charged, their discussions provided invaluable information as to the design and implementation of the alternatives.

One of the contributions the panel made to the planning process was to group the restoration components into geographical areas of concern in the lagoon. These areas are "North," "Central," and "South," as illustrated in Figure 4.8 (page 4-20). Not only does it facilitate discussion of the "problem areas" of the lagoon, but it also keeps together the components that complement each other hydraulically. Because there are two Pine Gulch Creek Delta variations (Riparian and Estuarine), there are two Central alternatives: Central (Riparian) and Central (Estuarine). In addition, due to potential public opposition and other significant issues, such as long term operations and maintenance responsibilities, involved with the implementation of the Seadrift Lagoon component, a consensus was reached at the June 29, 2001 Alternatives Review Conference (held by the Corps of Engineers San Francisco District and MCOSD) to develop the South (No Seadrift) alternative, which excludes the Seadrift Lagoon component. This section describes the composition of these alternatives (illustrated in Table 4.4, page 4-24) and how they were combined to form the alternative plans. Specifics of the expert panel process will be described later in the document. Alternative footprint surface areas and dredge volumes are detailed in Figure 4.9 (page 4-21).

### 4.4.1 No Action Alternative

The No Action alternative involves taking no further action to address sedimentation in the lagoon, but leaving in place the existing management plans and policies. This would include the Bolinas Lagoon Management Plan, existing management plans and policies administered by other authorities such as the Gulf of the Farallones National Marine Sanctuary, Golden Gate National Recreation Area, and Point Reyes National Seashore, as well as state and federal resource management laws and regulations. All of the restoration alternatives will be evaluated against the No Action alternative to determine the benefits and risks associated with each of the proposed alternatives.

### 4.4.2 North Alternative

The North Alternative is composed of the North Basin and Main Channel components. It was developed as a way to increase tidal prism in the entire lagoon, as well as increase subtidal and intertidal habitats. As stated earlier, the effectiveness of the North Basin improves when the Main Channel connects the basin to the inlet. Because the North Basin needs an adequate supply of water to fill it, thereby realizing more of its potential tidal prism, excavation in the North Basin and Main Channel are coupled. There would be 183 acres of diving duck habitat surface area, and 513,000 cy of diving duck habitat volume with the North Alternative (Table 4.5, page 4-25). Upland habitat

**Table 4.1 Upland Habitat Changes With Each Restoration Component**

| *Alternative* | 1998 Levels Surface Area acres | Constructed Surface Area acres | Change In Habitat Surface Area acres |
|---|---|---|---|
| **Bolinas Channel** | 2.54 | 0.05 | -2.50 |
| **Pine Gulch Delta (Estuarine)** | 30.59 | 19.47 | -11.12 |
| **Pine Gulch Delta (Riparian)** | 15.08 | 6.48 | -8.60 |
| **Kent Island** | 79.18 | 14.93 | -64.25 |
| **Dipsea Road Fill** | 6.02 | 3.69 | -2.33 |
| **Highway 1 Fills** | 1.81 | 1.40 | -0.40 |
| **South Arm Channel** | 0.08 | 0.01 | -0.07 |
| **Seadrift Lagoon** | 43.47 | 1.68 | -41.79 |
| **Main Channel** | 0.00 | 0.00 | 0.00 |
| **North End Basin** | 0.18 | 0.00 | -0.18 |
| | | **Net Change** | **-131.24** |

**Table 4.2 Intertidal Habitat Changes With Each Restoration Component**

| *Alternative* | 1998 Levels | | Constructed | | Change In Habitat | |
|---|---|---|---|---|---|---|
| | Surface Area | Volume | Surface Area | Volume | Surface Area | Volume |
| | acres | cy | acres | cy | acres | cy |
| **Bolinas Channel** | 12.86 | 31,025 | 1.51 | 93,933 | -11.35 | 62,908 |
| **Pine Gulch Delta (Estuarine)** | 72.24 | 137,955 | 79.81 | 293,095 | 7.58 | 155,140 |
| **Pine Gulch Delta (Riparian)** | 71.24 | 137,142 | 75.92 | 285,417 | 4.68 | 148,275 |
| **Kent Island** | 44.88 | 45,123 | 93.04 | 276,387 | 48.17 | 231,263 |
| **Dipsea Road Fill** | 1.95 | 3,567 | 5.25 | 17,314 | 3.29 | 13,747 |
| **Highway 1 Fills** | 1.45 | 2,065 | 1.98 | 4,549 | 0.53 | 2,484 |
| **South Arm Channel** | 14.52 | 84,552 | 0.66 | 109,983 | -13.86 | 25,431 |
| **Seadrift Lagoon** | 0.00 | 0 | 6.75 | 245,414 | 6.75 | 245,414 |
| **Main Channel** | 34.14 | 126,102 | 1.74 | 234,683 | -32.40 | 108,581 |
| **North End** | 108.81 | 689,450 | 2.28 | 855,476 | -106.53 | 166,027 |
| | | | | **Net Change** | **-93.14** | **1,159,270** |

**Table 4.3  Subtidal Habitat Changes With Each Restoration Component**

| *Alternative* | 1998 Levels | | Constructed | | Change In Habitat | |
|---|---|---|---|---|---|---|
| | Surface Area | Volume | Surface Area | Volume | Surface Area | Volume |
| | Acres | cy | acres | cy | acres | cy |
| **Bolinas Channel** | 0.16 | 376 | 13.92 | 66,715 | 13.76 | 66,339 |
| **Pine Gulch Delta (Estuarine)** | 0.00 | 0 | 3.93 | 813 | 3.93 | 813 |
| **Pine Gulch Delta (Riparian)** | 0.00 | 0 | 3.92 | 810 | 3.92 | 810 |
| **Kent Island** | 0.01 | 0 | 16.27 | 16,395 | 16.26 | 16,394 |
| **Dipsea Road Fill** | 0.00 | 0 | 0.10 | 333 | 0.10 | 333 |
| **Highway 1 Fills** | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 |
| **South Arm Channel** | 2.99 | 3,147 | 16.91 | 66,577 | 13.93 | 63,431 |
| **Seadrift Lagoon** | 0.00 | 0 | 35.16 | 186,285 | 35.16 | 186,285 |
| **Main Channel** | 3.35 | 3,037 | 35.76 | 110,745 | 32.40 | 107,708 |
| **North End Basin** | 27.11 | 18,402 | 133.82 | 310,822 | 106.71 | 292,421 |
| | | | | **Net Change** | **226.18** | **734,533** |

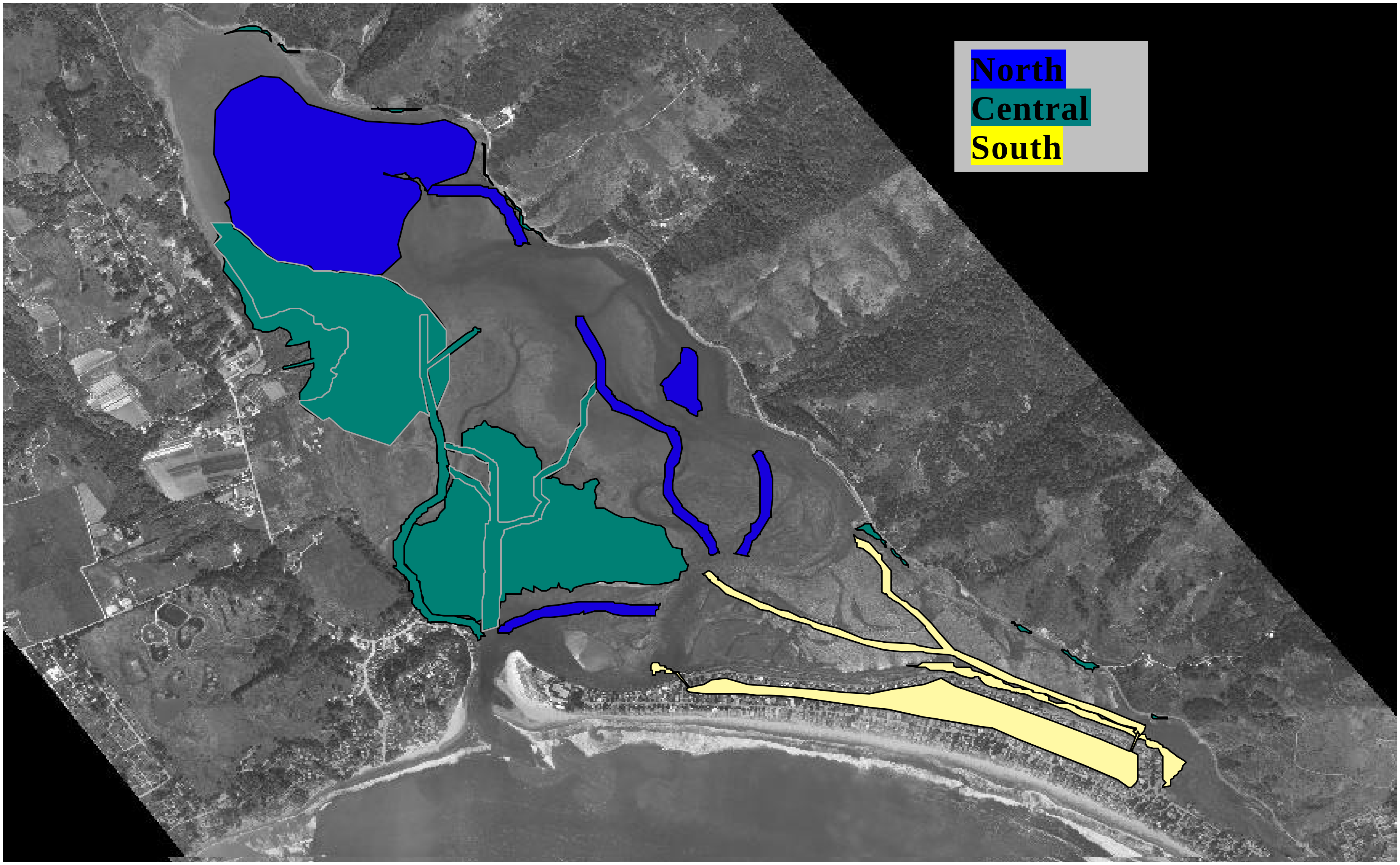
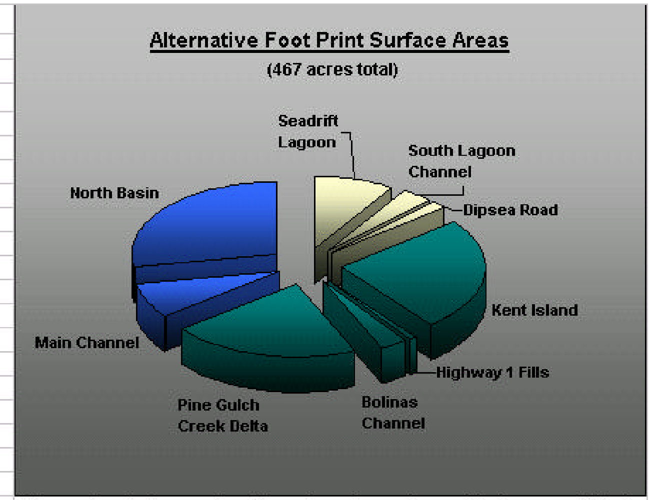


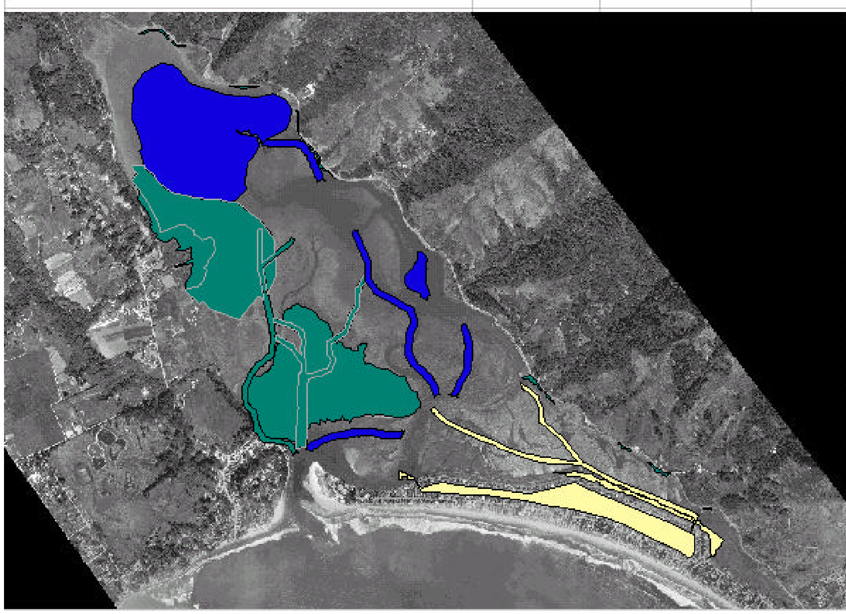

*Figure 4.8 Map of Fundamental Geographical Areas*

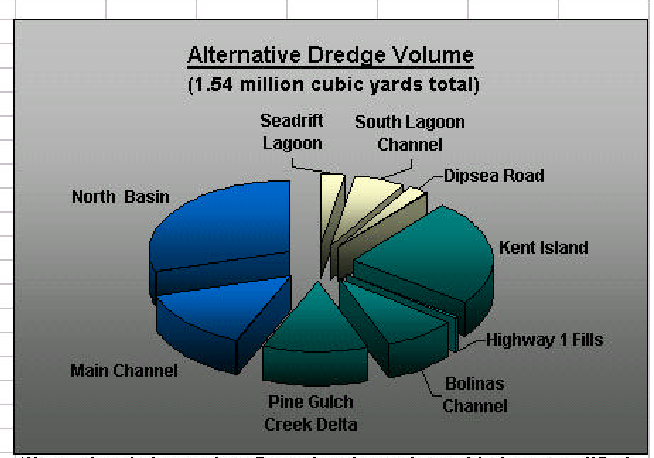
**Alternative Footprint Areas and Dredge Volumes**

| Alternative | Surface Area acres | Dredge Volume $yds^3$ |
|---|---|---|
| North | 173.60 | 674,778 |
| Central (Estuarine) | 245.71 | 703,081 |
| Central (Riparian) | 229.20 | 670,993 |
| South (Seadrift) | 69.02 | 171,897 |
| South (No Seadrift) | 25.55 | 126,939 |
| North and Central (Estuarine) | 419.31 | 1,377,860 |
| North and Central (Riaprian) | 402.80 | 1,345,771 |
| North and South (Seadrift) | 242.62 | 846,675 |
| North and South (No Seadrift) | 199.15 | 801,717 |
| Central (Estuarine) and South (Seadrift) | 314.73 | 874,978 |
| Central (Estuarine) and South (No Seadrift) | 271.26 | 830,020 |
| Central (Riparian) and South (Seadrift) | 298.22 | 842,889 |
| Central (Riparian) and Soth (No Seadrift) | 254.75 | 797,931 |
| North, Central (Estuarine), and South (Seadrift) | 488.33 | 1,549,757 |
| North, Central (Estuarine), and South (No Seadrift) | 444.86 | 1,504,799 |
| North, Central (Riparian), and South (Seadrift) | 471.82 | 1,517,668 |
| North, Central (Riparian), and South (No Seadrift) | 428.35 | 1,472,710 |




*Note - the pi chart only reflects the alternatives with the unmodified components.






*Note - the pi chart only reflects the alternatives with the unmodified components.

*Figure 4.9 Alternative Footprint Surface Area and Dredge Volumes* surface area would decrease by 34 acres (Table 4.6, page 4-25). Intertidal habitat surface area would decrease by 99 acres, but intertidal habitat volume would increase by 735,000 cy (Table 4.7, page 4-25). Subtidal habitat surface area would increase by 134 acres, and subtidal habitat volume would increase by 362,000 cy (Table 4.8, page 4-25). A total of 675,000 cubic yards of material would be removed with this alternative, and the total footprint surface area for this alternative would be 174 acres (Figure 4.9).

### 4.4.3 Central (Estuarine) Alternative

The Central (Estuarine) Alternative is composed of Pine Gulch Creek Delta (Estuarine) component, Bolinas Channel, Kent Island and the Highway One Fills components. Pine Gulch Creek Delta, Kent Island and Bolinas Channel are all linked because of their combined effects on the central part of the lagoon. Pine Gulch Creek, draining half of the watershed into the lagoon, is a significant contributor of sediment in the lagoon and plays an important role in the dynamic relationship between the lagoon and the watershed. All of the components in this alternative affect (and are affected by) Pine Gulch Creek. For example, excavation in these areas not only improves intertidal and subtidal habitat, but also improves habitat quality and access to Pine Gulch Creek for the anadromous fish species that inhabit the lagoon. The Highway One Fills component can easily fit into any of the geographic areas of the lagoon, but considering that the fills span north to south on the eastern side of the lagoon, they have been included in the Central alternative. There would be 93 acres of diving duck habitat surface area, and 412,000 cy of diving duck habitat volume with the Central (Estuarine) Alternative (Table 4.5, page 4-25). Upland habitat surface area would decrease by 98 acres (Table 4.6, page 4-25). Intertidal habitat surface area would increase by 73 acres, and intertidal habitat volume would increase by 869,000 cy (Table 4.7, page 4-25). Subtidal habitat surface area would increase by 26 acres, and subtidal habitat volume would increase by 67,000 cy (Table 4.8, page 4-25). A total of 703,000 cubic yards of material would be removed with this alternative, and the total footprint surface area for this alternative would be 246 acres (Figure 4.9, page 4-21).

### 4.4.4 Central (Riparian) Alternative

The Central (Riparian) Alternative is similar to the Central (Estuarine) Alternative except that the Pine Gulch Creek Delta (Riparian) component avoids the riparian habitat on the delta. This alternative is composed of Pine Gulch Creek Delta (Riparian) component, Bolinas Channel, Kent Island and the Highway One Fills components. Pine Gulch Creek Delta, Kent Island and Bolinas Channel are all linked because of their combined effects on the central part of the lagoon. Pine Gulch Creek, draining half of the watershed into the lagoon, is a significant contributor of sediment in the lagoon and plays an important role in the dynamic relationship between the lagoon and the watershed. All of the components in this alternative affect (and are affected by) Pine Gulch Creek. For example, excavation in these areas not only improves intertidal and subtidal habitat, but also improves habitat quality and access to Pine Gulch Creek for the anadromous fish species that inhabit the lagoon. The Highway One Fills component can easily fit into any of the geographic areas of the lagoon, but considering that the fills span north to south on the eastern side of the lagoon, they have been included in the Central alternative. There would be 93 acres of diving duck habitat surface area, and 412,000 cy of diving duck habitat volume with the Central (Riparian) Alternative (Table 4.5, page 4-25). Upland habitat surface area would decrease by 95 acres (Table 4.6, page 4-25). Intertidal habitat surface area would decrease by 70 acres, but intertidal habitat volume would increase by 863,000 cy (Table 4.7, page 4-25). Subtidal habitat surface area would increase by 134 acres, and subtidal habitat volume would increase by 67,000 cy (Table 4.8, page 4-25). A total of 671,000 cubic yards of material would be removed with this alternative, and the total footprint surface area for this alternative would be 229 acres (Figure 4.9, page 4-21).

### 4.4.5 South (Seadrift) Alternative

The South (Seadrift) Alternative is composed of the South Lagoon Channel, Dipsea Road and Seadrift Lagoon components. Seadrift Lagoon is linked to the South Lagoon Channel because the southeastern opening of Seadrift Lagoon needs a supply of water, and because linking the two generally helps improve water circulation in the south part of the lagoon. The Dipsea Road Fills component also improves circulation (and intertidal habitat) in the south. The South (Seadrift) Alternative restores tidal prism and increases intertidal and subtidal habitat in the southern part of Bolinas Lagoon. Other benefits include increased access for anadramous fish to Easkoot Creek, and improved habitat value in Seadrift Lagoon. There would be 100 acres of diving duck habitat surface area, and 437,000 cy of diving duck habitat volume with the South (Seadrift) Alternative (Table 4.5, page 4-25). Upland habitat surface area would decrease by 30 acres (Table 4.6, page 4-25). Intertidal habitat surface area would increase by 31 acres, and intertidal habitat volume would increase by 651,000 cy (Table 4.7, page 4-25). Subtidal habitat surface area would increase by 44 acres, and subtidal habitat volume would increase by 236,000 cy (Table 4.8, page 4-25). A total of 172,000 cubic yards of material would be removed with this alternative, and the total footprint surface area for this alternative would be 69 acres (Figure 4.9, page 4-21).

### 4.4.6 South (No Seadrift) Alternative

The South (No Seadrift) Alternative is composed of the South Lagoon Channel and Dipsea Road components, but does *not* include the Seadrift Lagoon component. Without Seadrift Lagoon, this alternative has limited habitat value, but it does restore intertidal and subtidal habitat that has been lost in this area. In addition, although the South Lagoon Channel would no longer be connecting Seadrift Lagoon to the Main Channel, it can still increase tidal flow and subtidal habitat value in the area. The Dipsea Road Fills component improves circulation and intertidal habitat. The South (No Seadrift) Alternative restores tidal prism and increases intertidal and subtidal habitat in the southern part of Bolinas Lagoon. Other benefits include increased access to anadramous fish to Easkoot Creek, and improved habitat value in Seadrift Lagoon. There would be 71 acres of diving duck habitat surface area, and 355,000 cy of diving duck habitat volume with the South (No Seadrift) Alternative (Table 4.5, page 4-25). Upland habitat surface area would decrease by 9 acres (Table 4.6, page 4-25). Intertidal habitat surface area would decrease by 8 acres, but intertidal habitat volume would increase by

**Table 4.4 Composition of Alternatives**

| | North Basin | Main Channel | Bolinas Channel | Kent Island | Highway 1 Fills | Pine Gulch Creek Delta (Estuarine) | Pine Gulch Creek Delta (Riparian) | Dipsea Road | South Lagoon Channel | Seadrift Lagoon |
|---|---|---|---|---|---|---|---|---|---|---|
| Alternative North | X | X | | | | | | | | |
| Alternative Central (Estuarine) | | | X | X | X | X | | | | |
| Alternative Central (Riparian) | | | X | X | X | | X | | | |
| Alternative South (No Seadrift) | | | | | | | | X | X | |
| Alternative South (Seadrift) | | | | | | | | X | X | X |

**Table 4.5 Diving Duck Habitat (1m to 3m below MSL; -2.70' and 8.70' NGVD) with Each Alternative**

| *Summary* | Surface Area<br>acres | Volume<br>cy |
|---|---|---|
| 1968 | 95.64 | 379,986 |
| 1998 | 51.65 | 292,876 |
| North | 183.01 | 512,613 |
| Central (Estuarine) | 92.90 | 412,406 |
| Central (Riparian) | 92.90 | 412,406 |
| South (Seadrift) | 99.54 | 437,232 |
| South (No Seadrift) | 70.95 | 355,483 |

**Table 4.6 Upland Habitat Changes with Each Alternative**

| *Alternative Plan* | 1998 Levels<br>Surface Area<br>Acres | Constructed<br>Surface Area<br>acres | Change In Habitat<br>Surface Area<br>acres |
|---|---|---|---|
| North | 238.10 | 204.04 | -34.06 |
| Central (Estuarine) | 238.10 | 140.04 | -98.06 |
| Central (Riparian) | 238.10 | 143.61 | -94.49 |
| South (Seadrift) | 238.10 | 208.05 | -30.05 |
| South (No Seadrift) | 238.10 | 229.31 | -8.79 |

**Table 4.7 Intertidal Habitat Changes with Each Alternative**

| *Alternative Plan* | 1998 Levels | | Constructed | | Change In Habitat | |
|---|---|---|---|---|---|---|
| | Surface Area<br>Acres | Volume<br>cy | Surface Area<br>acres | Volume<br>cy | Surface Area<br>acres | Volume<br>cy |
| North | 848.53 | 3,584,714 | 749.05 | 4,319,597 | -99.48 | 734,883 |
| Central (Estuarine) | 848.53 | 3,584,714 | 921.75 | 4,453,670 | 73.22 | 868,956 |
| Central (Riparian) | 848.53 | 3,584,714 | 918.06 | 4,448,117 | 69.54 | 863,403 |
| South (Seadrift) | 848.53 | 3,584,714 | 879.34 | 4,235,852 | 30.81 | 651,138 |
| South (No Seadrift) | 848.53 | 3,584,714 | 840.98 | 3,698,360 | -7.55 | 113,646 |

**Table 4.8 Subtidal Habitat Changes with Each Alternative**

| *Alternative Plan* | 1998 Levels | | Constructed | | Change In Habitat | |
|---|---|---|---|---|---|---|
| | Surface Area<br>Acres | Volume<br>cy | Surface Area<br>acres | Volume<br>cy | Surface Area<br>acres | Volume<br>cy |
| North | 146.39 | 523,318 | 279.94 | 885,096 | 133.54 | 361,778 |
| Central (Estuarine) | 146.39 | 523,318 | 171.92 | 589,858 | 25.52 | 66,540 |
| Central (Riparian) | 146.39 | 523,318 | 171.87 | 589,852 | 25.48 | 66,534 |
| South (Seadrift) | 146.39 | 523,318 | 190.33 | 759,606 | 43.94 | 236,289 |
| South (No Seadrift) | 146.39 | 523,318 | 163.85 | 590,120 | 17.46 | 66,802 |

114,000 cy (Table 4.7, page 4-25). Subtidal habitat surface area would increase by 17 acres, and subtidal habitat volume would increase by 67,000 cy (Table 4.8, page 4-25). A total of 127,000 cubic yards of material would be removed with this alternative, and the total footprint surface area for this alternative would be 26 acres (Figure 4.9, page 4-21).

## 4.5 Formulation of Alternative Plans and Preliminary Screening

Combining the restoration components to form the alternatives North, Central (Estuarine), Central (Riparian), South (Seadrift) and South (No Seadrift) helped to reduce the final number of alternative plans to be considered. If each component were considered an alternative, the combinations of alternatives would be too numerous (over 1000 permutations), making the analysis very difficult. In addition, grouping them geographically is logical since the restoration components have a synergy, often improving in function when combined, and also addressing problem areas of the lagoon when grouped this way. It should be noted that this grouping is flexible, and is *not* required. The tentatively selected plan, for example, could include any number of components, depending on habitat improvements desired, lagoon function desired, and feasibility, constructability, cost, or public acceptance of the components. For this Feasibility Study, grouping the components simplifies the analysis. With only three geographical restoration areas to combine, including two variations each of the Central and South Alternatives, the number of permutations was seventeen. The alternative plans are as follows:

1. North
2. Central (Estuarine)
3. Central (Riparian)
4. South (Seadrift)
5. South (No Seadrift)
6. North and Central (Estuarine)
7. North and Central (Riparian)
8. North and South (Seadrift)
9. North and South (No Seadrift)
10. Central (Estuarine) and South (Seadrift)
11. Central (Estuarine) and South (No Seadrift)
12. Central (Riparian) and South (Seadrift)
13. Central (Riparian) and South (No Seadrift)
14. North, Central (Estuarine), and South (Seadrift)
15. North, Central (Estuarine), and South (No Seadrift)
16. North, Central (Riparian), and South (Seadrift)
17. North, Central (Riparian), and South (No Seadrift)

Figure 4.9 (page 4-21) shows the surface area and dredge volumes associated with each geographical area/alternative. These numbers simply reflect the cumulative surface areas and volumes of the components that are included in each alternative.

Once the alternatives were combined into alternative plans, the number of alternative plans still needed to be reduced to a reasonable number for further analysis. Because some of the alternative plans are more effective at achieving the project goals, the study team needed to establish criteria by which to evaluate the alternative plans. Ranking the alternative plans by how well they meet the goals of the project identifies which plans are not as effective and should therefore be eliminated from further analysis.

The Habitat Evaluation Expert Panel was presented with this task. Although they established ecological and hydrological criteria, they were unable to justify ranking any of the alternatives above any of the others using the ecological criteria. Understanding the relationship between the hydrology and the ecology of the system, and knowing that increases in intertidal and subtidal habitats would bring about certain ecological benefits, the study team decided that the best way of evaluating the alternative plans would be to rank them based on a hydrological parameter that was related to some of the ecological criteria defined by the expert panel. Intertidal volume (measured in cubic yards) was chosen as this key parameter, based on three criteria:

1. Intertidal Volume addresses most of the issues in the purpose and need of the project (i.e., project objectives).

2. Historical and projected future habitat losses – intertidal habitat has been the prime habitat type lost in the lagoon system; based on historical data, it will continue to decrease significantly.

3. Hydraulic affects – by definition, any alternative that increases intertidal volume increases tidal prism. This has a direct correlation to lagoon flushing and inlet stability.

In order to compare the alternative plans and carry out the incremental cost analysis, one key parameter needed to represent the benefits of each alternative. A tangible number that is equal in relative value for each alternative is especially important. This does not mean that all of the other parameters mentioned were ignored or will be ignored in the decision making process. They will certainly be looked at for effects and impacts that would be of benefit or concern. However, intertidal volume is a parameter that is easy to use and has both hydrological and ecological benefits. The expert panel agreed that a ranking based on intertidal volume was an appropriate indicator of effectiveness at achieving the project goals.

Figure 4.10 (page 4-30) shows all of the alternative plans and how intertidal volume changes with each one. The order is not surprising. In general, as more sediment is removed, the intertidal volume benefits increase. For the initial screening process, the top twelve (out of seventeen) alternative plans were identified for further analysis. Because intertidal volume addresses many of the project restoration goals (to increase intertidal and subtidal habitat, increase tidal prism, and reduce the chance for inlet closure), it was assumed that the smaller alternatives did not do enough to achieve those goals, and were therefore eliminated during the preliminary screening process. Because regularly scheduled maintenance dredging was not a management option for the lagoon due to permitting restrictions of the GFNMS, the final array of alternatives needed to provide a significant increase in tidal prism and intertidal and subtidal habitats. Increases in all three reduce the potential for inlet closure, and thus improve the function of the lagoon as a system. The smallest plans did not meet the preliminary screening criteria. The final array of alternative plans is listed below (composition of alternative plans shown in Table 4.9).

1. North, Central (Estuarine) and South (Seadrift)
2. North, Central (Estuarine) and South (No Seadrift)
3. North, Central (Riparian) and South (Seadrift)
4. North, Central (Riparian) and South (No Seadrift)
5. North and Central (Estuarine)
6. North and Central (Riparian)
7. Central (Estuarine) and South (Seadrift)
8. Central (Estuarine) and South (No Seadrift)
9. Central (Riparian) and South (Seadrift)
10. Central (Riparian) and South (No Seadrift)
11. North and South (Seadrift)
12. North and South (No Seadrift)

## 4.6 Final Array of Alternative Plans

### 4.6.1 No Action Alternative Plan

The No Action alternative involves taking no further action to address sedimentation in the lagoon, but leaving in place the existing management plans and policies. This would include the Bolinas Lagoon Management Plan, existing management plans and policies administered by other authorities such as the Gulf of the Farallones National Marine Sanctuary, Golden Gate National Recreation Area, and Point Reyes National Seashore, as well as state and federal resources management laws and regulations. It is assumed that with this plan, sediment would continue to fill the lagoon, and the potential for inlet closure would continue to increase until about 2050, at which time inlet closure would become very likely. Overall, continued sedimentation would result in a continual decline in intertidal and subtidal habitats, and diminishing habitat values associated with each. Although there would be some short term benefits to emergent marsh species, eventually, all habitats would convert to upland, and species diversity would decrease significantly. All of the restoration alternatives will be evaluated against the No Action alternative to determine the benefits and risks associated with each of the proposed alternatives.

**Table 4.9 Composition of Alternative Plans**

| | North Basin | Main Channel | Bolinas Channel | Kent Island | Highway 1 Fills | Pine Gulch Creek Delta (Estuarine) | Pine Gulch Creek Delta (Riparian) | Dipsea Road | South Lagoon Channel | Seadrift Lagoon |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Alternative Plan North, Central (Estuarine) and South (Seadrift) | X | X | X | X | X | X | | X | X | X |
| 2. Alternative Plan North, Central (Estuarine) and South (No Seadrift) | X | X | X | X | X | X | | X | X | |
| 3. Alternative Plan North, Central (Riparian) and South (Seadrift) | X | X | X | X | X | | X | X | X | X |
| 4. Alternative Plan North, Central (Riparian) and South (No Seadrift) | X | X | X | X | X | | X | X | X | |
| 5. Alternative Plan North and Central (Estuarine) | X | X | X | X | X | X | | | | |
| 6. Alternative Plan North and Central (Riparian) | X | X | X | X | X | | X | | | |
| 7. Alternative Plan Central (Estuarine) and South (Seadrift) | | | X | X | X | X | | X | X | X |
| 8. Alternative Plan Central (Estuarine) and South (No Seadrift) | | | X | X | X | X | | X | X | |
| 9. Alternative Plan Central (Riparian) and South (Seadrift) | | | X | X | X | | X | X | X | X |
| 10. Alternative Plan Central (Riparian) and South (No Seadrift) | | | X | X | X | | X | X | X | |
| 11. Alternative Plan North and South (Seadrift) | X | X | | | | | | X | X | X |
| 12. Alternative Plan North and South (No Seadrift) | X | X | | | | | | X | X | |

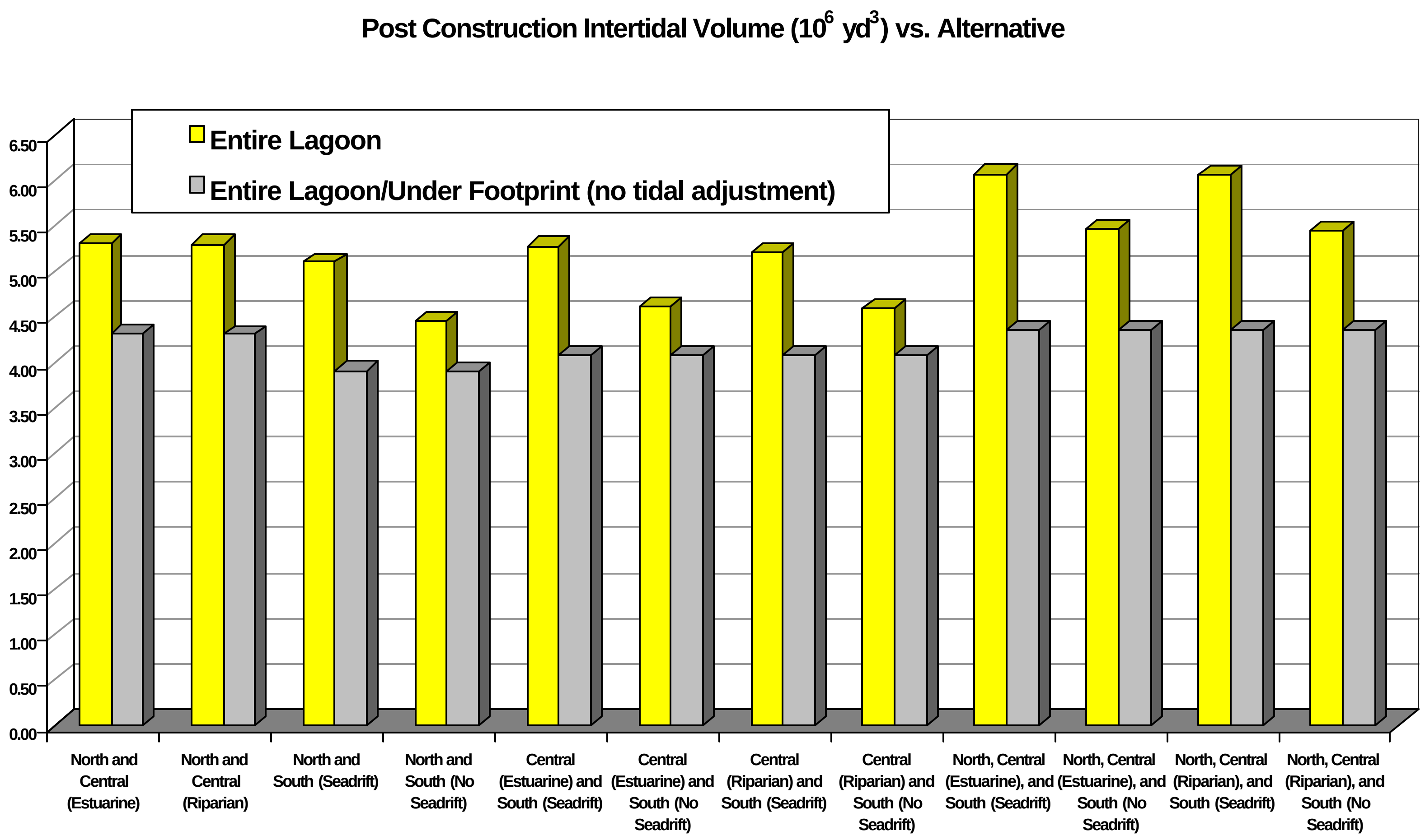



*Figure 4.10 Intertidal Habitat Volume Change with Each Restoration Alternative Plan*

### 4.6.2 North, Central (Estuarine), and South (Seadrift) Alternative Plan

This alternative plan would be considered the "full construction" plan, excavating material from all areas of the lagoon, including the North Basin, the Main Channel, the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel, Dipsea Road and Seadrift Lagoon. It incorporates the North, Central (Estuarine) and South (Seadrift) alternatives. There would be 214 acres of diving duck habitat surface area, and 613,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 123 acres (Table 4.11, page 4-36). Intertidal habitat surface area would increase by 14 acres, and intertidal habitat volume would increase by 2,490,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 155 acres, and subtidal habitat volume would increase by 442,000 cy (Table 4.13, page 4-38). A total of 1,550,000 cubic yards of material would be removed, and the construction footprint would cover 488 acres (Figure 4.9, page 4-21). Subtidal and intertidal habitat volume increases are not equal to the volume of material removed because the total amount of material removed includes only sediment, whereas habitat measurements, because they are in volume, include air and water space between the elevations that define each habitat.

### 4.6.3 North, Central (Estuarine), and South (No Seadrift) Alternative Plan

This alternative plan is similar to the full construction plan in that it includes the Pine Gulch Creek Delta (Estuarine) component, which includes excavation of some riparian habitat in the delta, but there is no proposed construction for the Seadrift Lagoon component. Excavation would take place in most areas of the lagoon, including the North Basin, the Main Channel, the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel and Dipsea Road. It incorporates the North, Central (Estuarine) and South (No Seadrift) alternatives. The South (No Seadrift) alternative consists only of Dipsea Road and the South Lagoon Channel. There would be 186 acres of diving duck habitat surface area, and 531,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 121 acres (Table 4.11, page 4-36). Intertidal habitat surface area would decrease by 16 acres, but intertidal habitat volume would increase by 1,876,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 138 acres, and subtidal habitat volume would increase by 367,000 cy (Table 4.13, page 4-38). A total of 1,505,000 cubic yards of material would be removed, and the construction footprint would cover 445 acres (Figure 4.9, page 4-21).

### 4.6.4 North, Central (Riparian) and South (Seadrift) Alternative Plan

This alternative plan is similar to the full construction plan, except that it includes the Pine Gulch Creek Delta (Riparian) component, which has a smaller footprint. Excavation would take place at all areas of the lagoon, including the North Basin, the Main Channel, the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel, Dipsea Road and Seadrift Lagoon. It incorporates the North, Central (Riparian) and South (Seadrift) alternatives. As previously mentioned, the Pine Gulch Creek Delta (Riparian) component is like the Pine Gulch Creek Delta (Estuarine) component in that it would remove portions of the large deltaic formation on the west side of the lagoon, but it would avoid the riparian habitat area entirely. There would be 214 acres of diving duck habitat surface area, and 613,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 119 acres (Table 4.11, page 4-36). Intertidal habitat surface area would increase by 8 acres, and intertidal habitat volume would increase by 2,476,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 156 acres, and subtidal habitat volume would increase by 447,000 cy (Table 4.13, page 4-38). A total of 1,518,000 cubic yards of material would be removed, and the construction footprint would cover 472 acres (Figure 4.9, page 4-21).

### 4.6.5 North, Central (Riparian) and South (No Seadrift) Alternative Plan

This alternative plan would be somewhat smaller than the full construction plan, with a smaller construction footprint in the delta area and no proposed construction in Seadrift Lagoon. Material would be excavated from most areas of the lagoon, including the North Basin, the Main Channel, the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel, and Dipsea Road. It incorporates the North, Central (Riparian) and South (No Seadrift) alternatives. As previously mentioned, the Pine Gulch Creek Delta (Riparian) component is like the Pine Gulch Creek Delta (Estuarine) component in that it would remove portions of the large deltaic formation on the west side of the lagoon, but it would avoid the riparian habitat area entirely. The South (No Seadrift) alternative consists only of Dipsea Road and the South Lagoon Channel. There would be 186 acres of diving duck habitat surface area, and 531,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 116 acres (Table 4.11, page 4-36). Intertidal habitat surface area would increase by 21 acres, and intertidal habitat volume would increase by 1,864,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 139 acres, and subtidal habitat volume would increase by 372,000 cy (Table 4.13, page 4-38). A total of 1,473,000 cubic yards of material would be removed, and the construction footprint would cover 429 acres (Figure 4.12, page 4-37).

### 4.6.6 North and Central (Estuarine) Alternative Plan

This alternative plan would include only the North and Central (Estuarine) alternatives, excavating material only from the North Basin, the Main Channel, the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, and Kent Island. None of the South restoration components would be constructed with this alternative plan. There would be 195 acres of diving duck habitat surface area, and 550,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 112 acres (Table 4.11, page 4-36). Intertidal habitat surface area would decrease by 13 acres, but intertidal habitat volume would increase by 1,720,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 127 acres, and subtidal habitat volume would increase by 332,000 cy (Table 4.13, page 4-38). A total of 1,378,000 cubic yards of material would be removed, and the construction footprint would cover 419 acres (Figure 4.9, page 4-21).

### 4.6.7 North and Central (Riparian) Alternative Plan

This alternative plan would include only the North and Central (Riparian) alternatives, and would be somewhat smaller than the North and Central (Estuarine) alternative plan. Material would be excavated from the North Basin, the Main Channel, the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, and Kent Island. As previously mentioned, the Pine Gulch Creek Delta (Riparian) component is like the Pine Gulch Creek Delta (Estuarine) component in that it would remove portions of the large deltaic formation on the west side of the lagoon, but it would avoid the riparian habitat area entirely. None of the South restoration components would be constructed in this alternative plan. There would be 195 acres of diving duck habitat surface area, and 550,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 108 acres (Table 4.11, page 4-36). Intertidal habitat surface area would decrease by 18 acres, but intertidal habitat volume would increase by 1,713,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 127 acres, and subtidal habitat volume would increase by 332,000 cy (Table 4.13, page 4-38). A total of 1,346,000 cubic yards of material would be removed, and the construction footprint would cover 403 acres (Figure 4.9, page 4-21).

### 4.6.8 Central (Estuarine) and South (Seadrift) Alternative Plan

This alternative plan would include only the Central (Estuarine) and South (Seadrift) alternatives. Material would be excavated from the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel, Dipsea Road and Seadrift Lagoon. None of the North restoration components would be constructed in this alternative plan. There would be 112 acres of diving duck habitat surface area, and 475,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 113 acres (Table 4.11, page 4-36). Intertidal habitat surface area would decrease by 109 acres, but intertidal habitat volume would increase by 1,693,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 49 acres, and subtidal habitat volume would increase by 230,000 cy (Table 4.13, page 4-38). A total of 875,000 cubic yards of material would be removed, and the construction footprint would cover 315 acres (Figure 4, page 4-21).

### 4.6.9 Central (Estuarine) and South (No Seadrift) Alternative Plan

This alternative plan would include only the Central (Estuarine) and South (No Seadrift) alternatives, and would be somewhat smaller than the Central (Estuarine) and South (Seadrift) alternative plan. Material would be excavated from the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel and Dipsea Road. The South (No Seadrift) alternative consists only of Dipsea Road and the South Lagoon Channel. None of the North restoration components would be constructed in this alternative plan. There would be 84 acres of diving duck habitat surface area, and 393,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 104 acres (Table 4.11, page 4-36). Intertidal habitat surface area would increase by 72 acres, and intertidal habitat volume would increase by 1,025,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 34 acres, and subtidal habitat volume would increase by

116,000 cy (Table 4.13, page 4-38). A total of 830,000 cubic yards of material would be removed, and the construction footprint would cover 271 acres (Figure 4.9, page 4-21).

### 4.6.10 Central (Riparian) and South (Seadrift) Alternative Plan

This alternative plan would include only the Central (Riparian) and South (No Seadrift) alternatives. Material would be excavated from the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel, Dipsea Road and Seadrift Lagoon. As mentioned earlier, the modified Pine Gulch Creek Delta component is like the original Pine Gulch Creek component in that it would remove portions of the large deltaic formation on the west side of the lagoon, but it would avoid the riparian habitat area entirely. None of the North restoration components would be constructed in this alternative plan. There would be 112 acres of diving duck habitat surface area, and 475,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 107 acres (Table 4.11, page 4-36). Intertidal habitat surface area would increase by 101 acres, and intertidal habitat volume would increase by 1,621,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 51 acres, and subtidal habitat volume would increase by 239,000 cy (Table 4.13, page 4-38). A total of 843,000 cubic yards of material would be removed, and the construction footprint would cover 298 acres (Figure 4.9, page 4-21).

### 4.6.11 Central (Riparian) and South (No Seadrift) Alternative Plan

This alternative plan would include only the Central (Riparian) and South (No Seadrift) alternatives, and would be somewhat smaller than the Central (Riparian) and South (Seadrift) alternative plan. Material would be excavated from the Highway One Fills, Pine Gulch Creek Delta, Bolinas Channel, Kent Island, the South Lagoon Channel and Dipsea Road. As mentioned earlier, the modified Pine Gulch Creek Delta component is like the original Pine Gulch Creek component in that it would remove portions of the large deltaic formation on the west side of the lagoon, but it would avoid the riparian habitat area entirely. None of the North restoration components would be constructed in this alternative plan. The South (No Seadrift) alternative consists only of Dipsea Road and the South Lagoon Channel. There would be 84 acres of diving duck habitat surface area, and 393,000 cy of diving duck habitat volume with this alternative plan (Table 4.10, page 4-35). Upland habitat surface area would decrease by 99 acres (Table 4.11, page 4-36). Intertidal habitat surface area would increase by 66 acres, and intertidal habitat volume would increase by 998,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 35 acres, and subtidal habitat volume would increase by 119,000 cy (Table 4.13, page 4-38). A total of 798,000 cubic yards of material would be removed, and the construction footprint would cover 255 acres (Figure 4.9, page 4-21).

### 4.6.12 North and South (Seadrift) Alternative Plan

This alternative plan would include only the North and South (Seadrift) alternatives. Material would be excavated from the North Basin, the Main Channel, the South Lagoon Channel, Dipsea Road and Seadrift Lagoon. None of the Central restoration components would be constructed with this alternative plan. There would be 202 acres of diving duck habitat surface area, and 575,000 cy of diving duck habitat volume with this alternative plan (Table 4.10). Upland habitat surface area would decrease by 58 acres (Table 4.11, page 4-36). Intertidal habitat surface area would decrease by 46 acres, but intertidal habitat volume would increase by 1,515,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 149 acres, and subtidal habitat volume would increase by 496,000 cy (Table 4.13, page 4-38). A total of 847,000 cubic yards of material would be removed, and the construction footprint would cover 243 acres (Figure 4.9, page 4-21).

**Table 4.10 Diving Duck Habitat with Each Alternative Plan**

| Summary | Surface Area acres | Volume cy |
|---|---|---|
| **1968** | 95.64 | 379,986 |
| **1998** | 51.65 | 292,876 |
| **North, Central (Riparian), and South (No Seadrift)** | 185.77 | 530,958 |
| **North, Central (Estuarine), and South (No Seadrift)** | 185.77 | 530,926 |
| **North and South (No Seadrift)** | 173.72 | 493,503 |
| **North and Central (Riparian)** | 195.06 | 550,069 |
| **North, Central (Estuarine), and South (Seadrift)** | 214.36 | 612,675 |
| **North, Central (Riparian), and South (Seadrift)** | 214.36 | 612,707 |
| **North and South (Seadrift)** | 202.31 | 575,252 |
| **North and Central (Estuarine)** | 195.06 | 550,069 |
| **Central (Estuarine) and South (Seadrift)** | 112.20 | 475,044 |
| **Central (Riparian) and South (Seadrift)** | 112.20 | 475,012 |
| **Central (Estuarine) and South (No Seadrift)** | 83.61 | 393,295 |
| **Central (Riparian) and South (No Seadrift)** | 83.61 | 393,263 |

### 4.6.13 North and South (No Seadrift) Alternative Plan

This alternative plan would include only the North and South (No Seadrift) alternatives, and is the smallest of the final array of alternative plans. Material would be excavated from the North Basin, the Main Channel, the South Lagoon Channel and Dipsea Road. The South (No Seadrift) alternative consists only of Dipsea Road and the South Lagoon Channel. None of the Central restoration components would be constructed with this alternative plan. There would be 174 acres of diving duck habitat surface area, and 494,000 cy of diving duck habitat volume (1m to 3m below MSL; -2.70' and 8.70' NGVD) with this alternative plan (Table 4.10). Upland habitat surface area would decrease by 41 acres (Table 4.11, page 4-36). Intertidal habitat surface area would decrease by 105 acres, and intertidal habitat volume would increase by 874,000 cy (Table 4.12, page 4-37). Subtidal habitat surface area would increase by 146 acres, and subtidal habitat volume would increase by 407,000 cy (Table 4.13, page 4-38). A total of 802,000 cubic yards of material would be removed, and the construction footprint would cover 199 acres (Figure 4.9, page 4-21).

**Table 4.11 Upland Habitat Changes with Each Alternative Plan**

| *Alternative Plan* | **1998 Levels Surface Area** acres | **Constructed Surface Area** acres | **Change In Habitat Surface Area** acres |
|---|---|---|---|
| **North and Central (Estuarine)** | 238.10 | 125.64 | -112.46 |
| **North and Central (Riparian)** | 238.10 | 130.07 | -108.03 |
| **North and South (Seadrift)** | 238.10 | 179.78 | -58.32 |
| **North and South (No Seadrift)** | 238.10 | 197.41 | -40.69 |
| **Central (Estuarine) and South (Seadrift)** | 238.10 | 125.39 | -112.71 |
| **Central (Estuarine) and South (No Seadrift)** | 238.10 | 134.28 | -103.82 |
| **Central (Riparian) and South (Seadrift)** | 238.10 | 131.15 | -106.95 |
| **Central (Riparian) and South (No Seadrift)** | 238.10 | 138.62 | -99.48 |
| **North, Central (Estuarine), and South (Seadrift)** | 238.10 | 115.05 | -123.05 |
| **North, Central (Estuarine), and South (No Seadrift)** | 238.10 | 117.47 | -120.63 |
| **North, Central (Riparian), and South (Seadrift)** | 238.10 | 119.59 | -118.51 |
| **North, Central (Riparian), and South (No Seadrift)** | 238.10 | 121.97 | -116.13 |

**Table 4.12 Intertidal Habitat Changes with Each Alternative Plan**

| | 1998 Levels | | Constructed | | Change In Habitat | |
|---|---|---|---|---|---|---|
| | Surface Area | Volume | Surface Area | Volume | Surface Area | Volume |
| ***Alternative Plan*** | acres | cy | acres | cy | acres | cy |
| **North and Central (Estuarine)** | 848.53 | 3,584,714 | 835.12 | 5,304,969 | -13.41 | 1,720,255 |
| **North and Central (Riparian)** | 848.53 | 3,584,714 | 830.54 | 5,297,813 | -17.99 | 1,713,100 |
| **North and South (Seadrift)** | 848.53 | 3,584,714 | 802.28 | 5,099,668 | -46.24 | 1,514,954 |
| **North and South (No Seadrift)** | 848.53 | 3,584,714 | 744.03 | 4,458,622 | -104.50 | 873,908 |
| **Central (Estuarine) and South (Seadrift)** | 848.53 | 3,584,714 | 957.79 | 5,277,954 | 109.26 | 1,693,240 |
| **Central (Estuarine) and South (No Seadrift)** | 848.53 | 3,584,714 | 920.04 | 4,609,638 | 71.51 | 1,024,924 |
| **Central (Riparian) and South (Seadrift)** | 848.53 | 3,584,714 | 949.20 | 5,205,799 | 100.67 | 1,621,085 |
| **Central (Riparian) and South (No Seadrift)** | 848.53 | 3,584,714 | 914.30 | 4,583,171 | 65.77 | 998,457 |
| **North, Central (Estuarine), and South (Seadrift)** | 848.53 | 3,584,714 | 862.34 | 6,074,382 | 13.82 | 2,489,668 |
| **North, Central (Estuarine), and South (No Seadrift)** | 848.53 | 3,584,714 | 832.87 | 5,460,468 | -15.66 | 1,875,754 |
| **North, Central (Riparian), and South (Seadrift)** | 848.53 | 3,584,714 | 856.68 | 6,061,159 | 8.15 | 2,476,445 |
| **North, Central (Riparian), and South (No Seadrift)** | 848.53 | 3,584,714 | 827.31 | 5,448,416 | -21.22 | 1,863,703 |

**Table 4.13 Subtidal Habitat Changes with Each Alternative Plan**

| | **1998 Levels** | | **Constructed** | | **Change In Habitat** | |
|---|---|---|---|---|---|---|
| | **Surface Area** | **Volume** | **Surface Area** | **Volume** | **Surface Area** | **Volume** |
| ***Alternative Plan*** | acres | cy | acres | cy | acres | cy |
| **North and Central (Estuarine)** | 146.39 | 523,318 | 272.94 | 855,584 | 126.55 | 332,266 |
| **North and Central (Riparian)** | 146.39 | 523,318 | 272.94 | 855,584 | 126.55 | 332,266 |
| **North and South (Seadrift)** | 146.39 | 523,318 | 295.64 | 1,019,817 | 149.25 | 496,499 |
| **North and South (No Seadrift)** | 146.39 | 523,318 | 292.70 | 930,011 | 146.31 | 406,693 |
| **Central (Estuarine) and South (Seadrift)** | 146.39 | 523,318 | 195.21 | 753,233 | 48.81 | 229,915 |
| **Central (Estuarine) and South (No Seadrift)** | 146.39 | 523,318 | 180.50 | 639,675 | 34.11 | 116,357 |
| **Central (Riparian) and South (Seadrift)** | 146.39 | 523,318 | 197.88 | 762,713 | 51.49 | 239,395 |
| **Central (Riparian) and South (No Seadrift)** | 146.39 | 523,318 | 181.75 | 642,561 | 35.35 | 119,243 |
| **North, Central (Estuarine), and South (Seadrift)** | 146.39 | 523,318 | 300.99 | 965,467 | 154.60 | 442,149 |
| **North, Central (Estuarine), and South (No Seadrift)** | 146.39 | 523,318 | 284.47 | 890,366 | 138.08 | 367,048 |
| **North, Central (Riparian), and South (Seadrift)** | 146.39 | 523,318 | 301.96 | 970,362 | 155.57 | 447,044 |
| **North, Central (Riparian), and South (No Seadrift)** | 146.39 | 523,318 | 285.39 | 894,995 | 139.00 | 371,677 |